NEW EW STATES IN PLAIN SIGHT

Patrick Meade
Yang Institute for Theoretical Physics
Stony Brook University

Based on:

D. Curtin, P. Jaiswal, PM 1206.6888

OR HOW I LEARNED TO STOP WORRYING AND LOVE SM MEASUREMENTS

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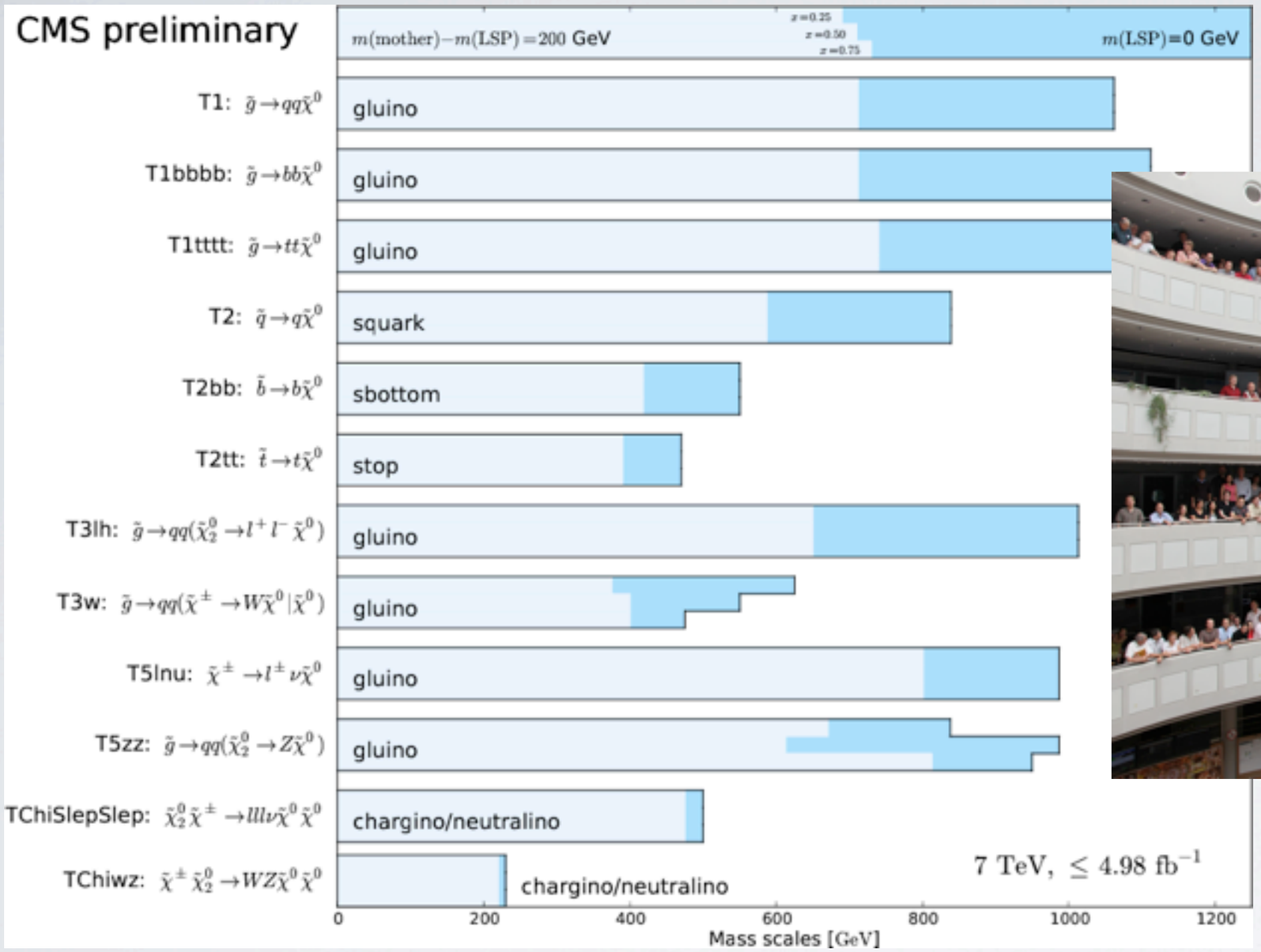
OUTLINE: A FAIRY TALE WITH CONSEQUENCES

- Experimental hints of nothing or something...
- New EW states to explain
- Constraints
- Other explanations?

SUSY SUSY NOWHERE...



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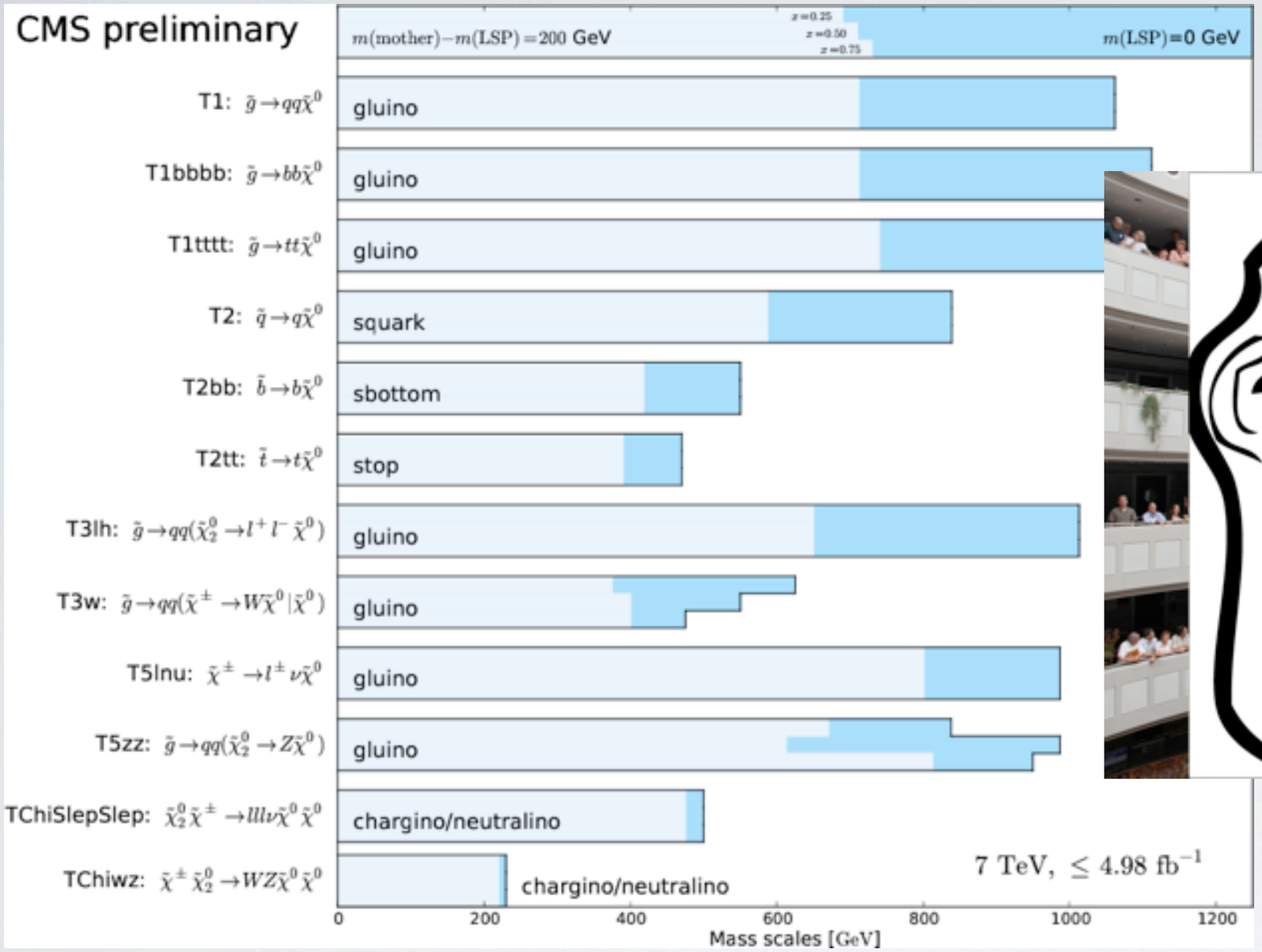
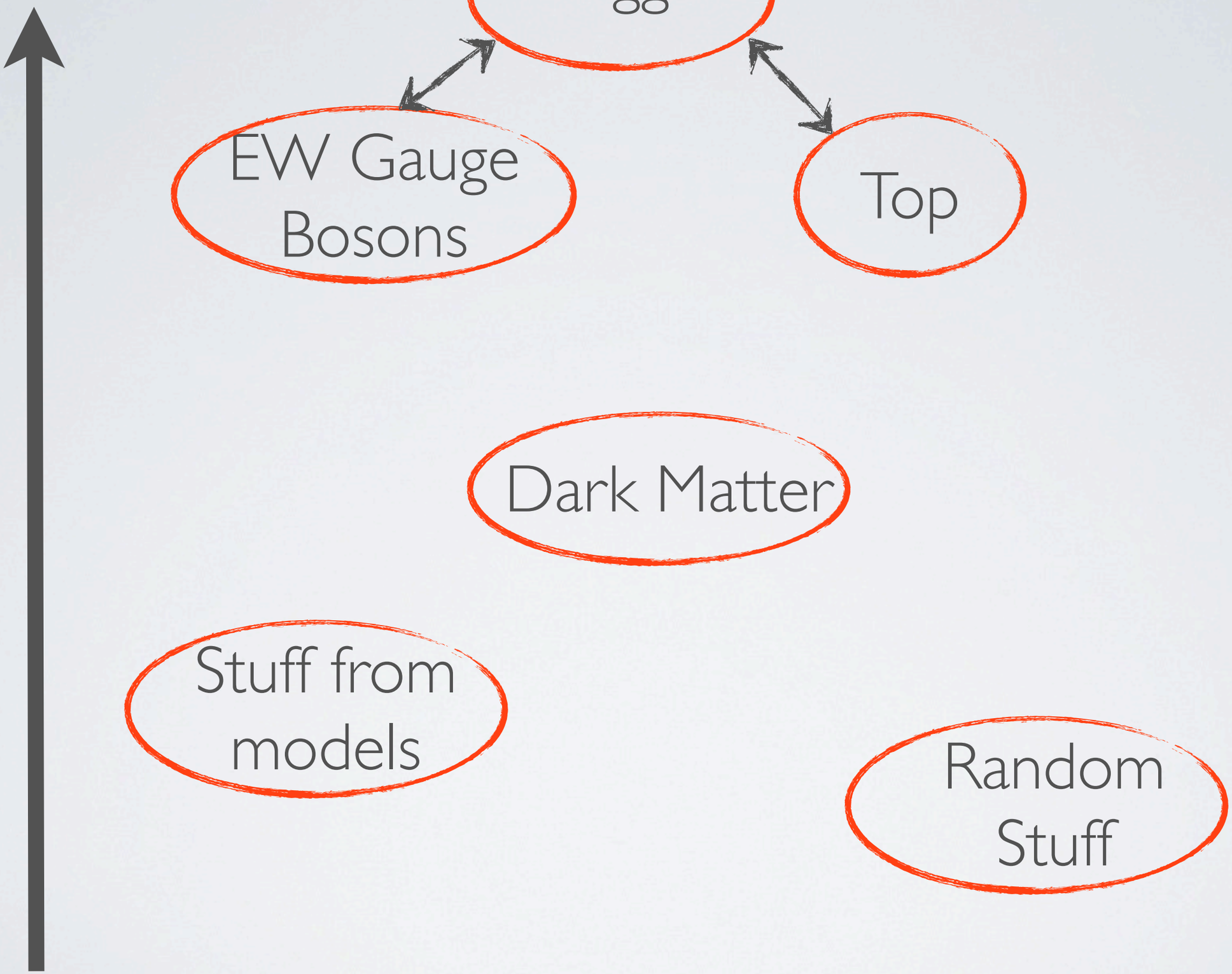


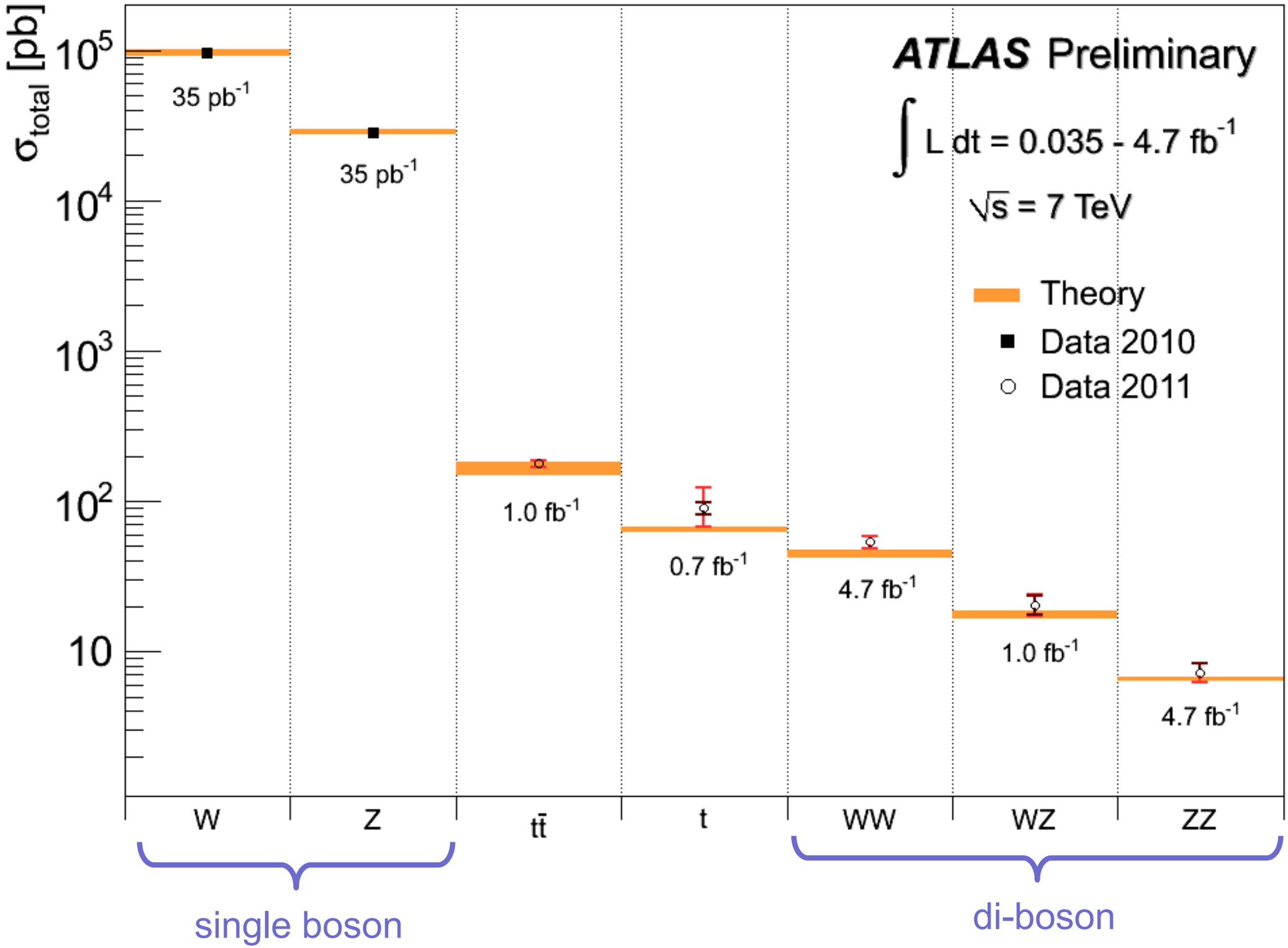
WHERE'S THE BEEF?

WHERE'S THE BEEF?
NEW PHYSICS?

IMPORTANCE TO LOOK FOR



SM CROSS SECTION PLOT



- Very similar agreement with (N)NLO predictions is observed by CMS

WW CROSS SECTION

- In principle the LHC makes 8 measurements highly sensitive to the WW cross section
  - SM WW at CMS7, ATLAS7, CMS8 ATLAS8
  - h→WW at CMS7, ATLAS7, CMS8, ATLAS8
- What's the status?

Every reported* measurement is higher than the SM

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NOT Fermi line high...

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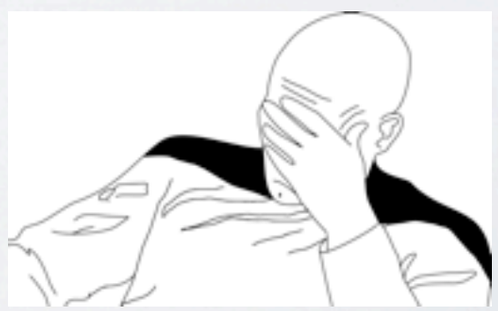
Every reported* measurement is higher than the SM

NOT Fermi line high...

Not astrophysics either...



WW CROSS SEC MEASUREMENTS

ATLAS 7

$$\sigma(pp \to W^+W^-) = 53.4 \pm 2.1(\text{stat}) \pm 4.5(\text{sys}) \pm 2.1(\text{lum})\ \text{pb}$$

CMS 7

$$\sigma(pp \to W^+W^-) = 52.4 \pm 2(\text{stat}) \pm 4.5(\text{sys}) \pm 1.2(\text{lum})\ \text{pb}$$

NLO theory at 7 TeV

$$\sigma(pp \to W^+W^-) = 45.1 \pm 2.8\,\text{pb}$$

ATLAS MC@NLO

$$\sigma(pp \to W^+W^-) = 47 \pm 2\,\text{pb}$$

MCFM **Campbell, Ellis, Williams**

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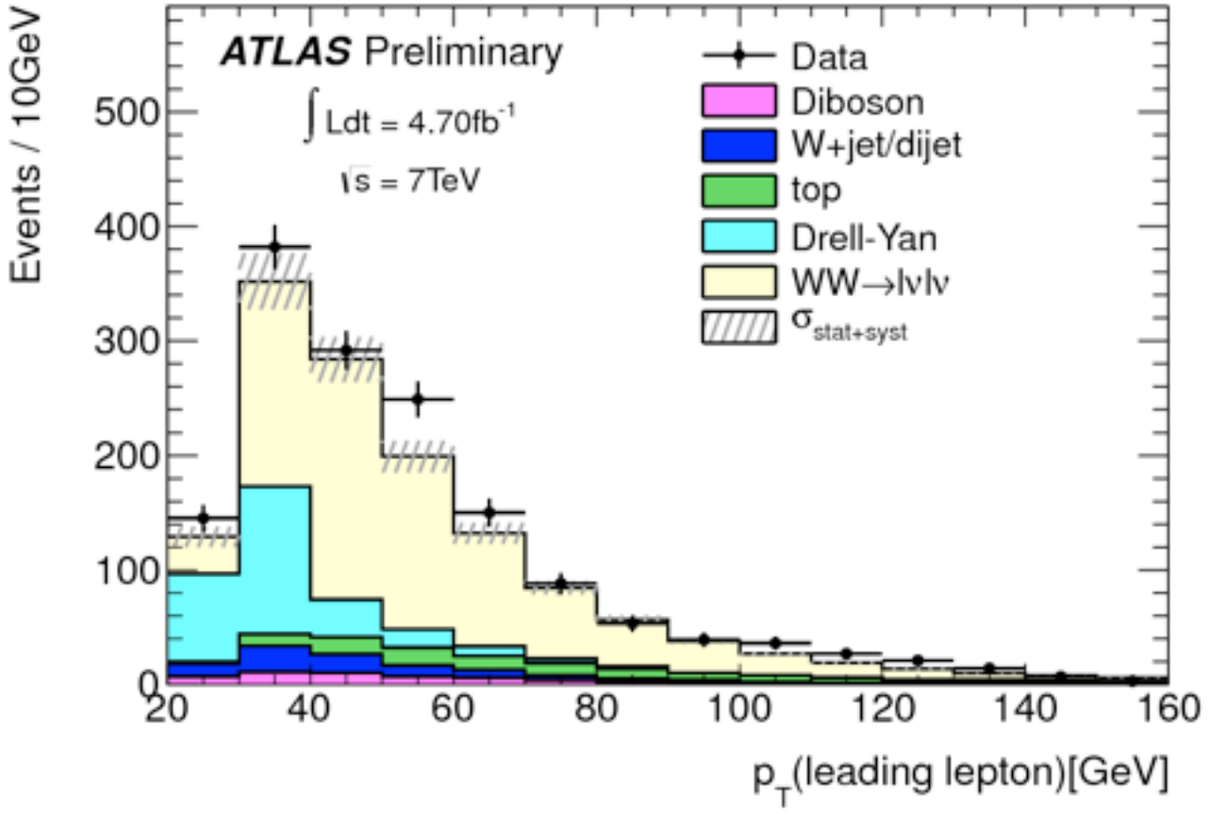
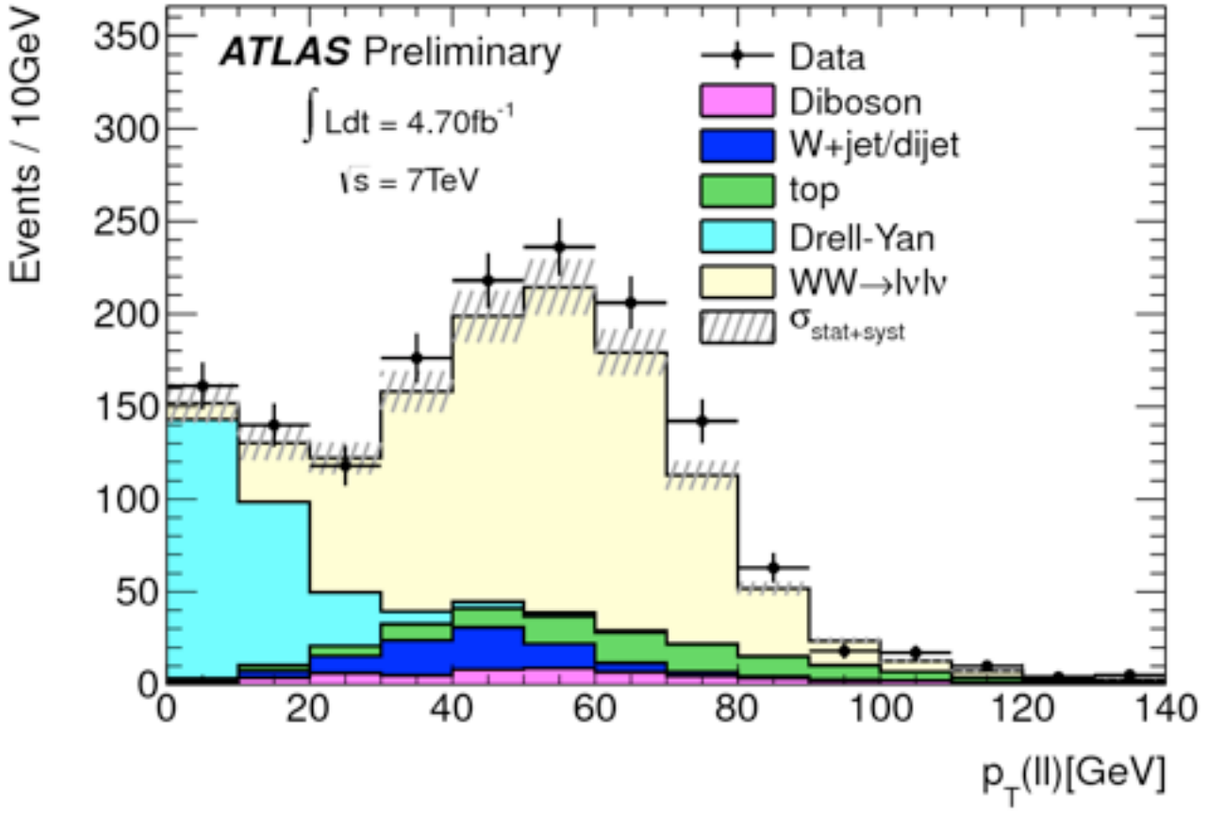
MCFM **Campbell, Ellis, Williams**

1.4σ and 1σ, this is an anomaly???

ATLAS and CMS are more consistent with each other than the SM...

NOT just a "rate" anomaly


ATLAS Preliminary
∫ Ldt = 4.70fb-1
√s = 7TeV
Data
Diboson
W+jet/dijet
top
Drell-Yan
WW→lνlν
σstat+syst
Events / 10GeV
pT(leading lepton)[GeV]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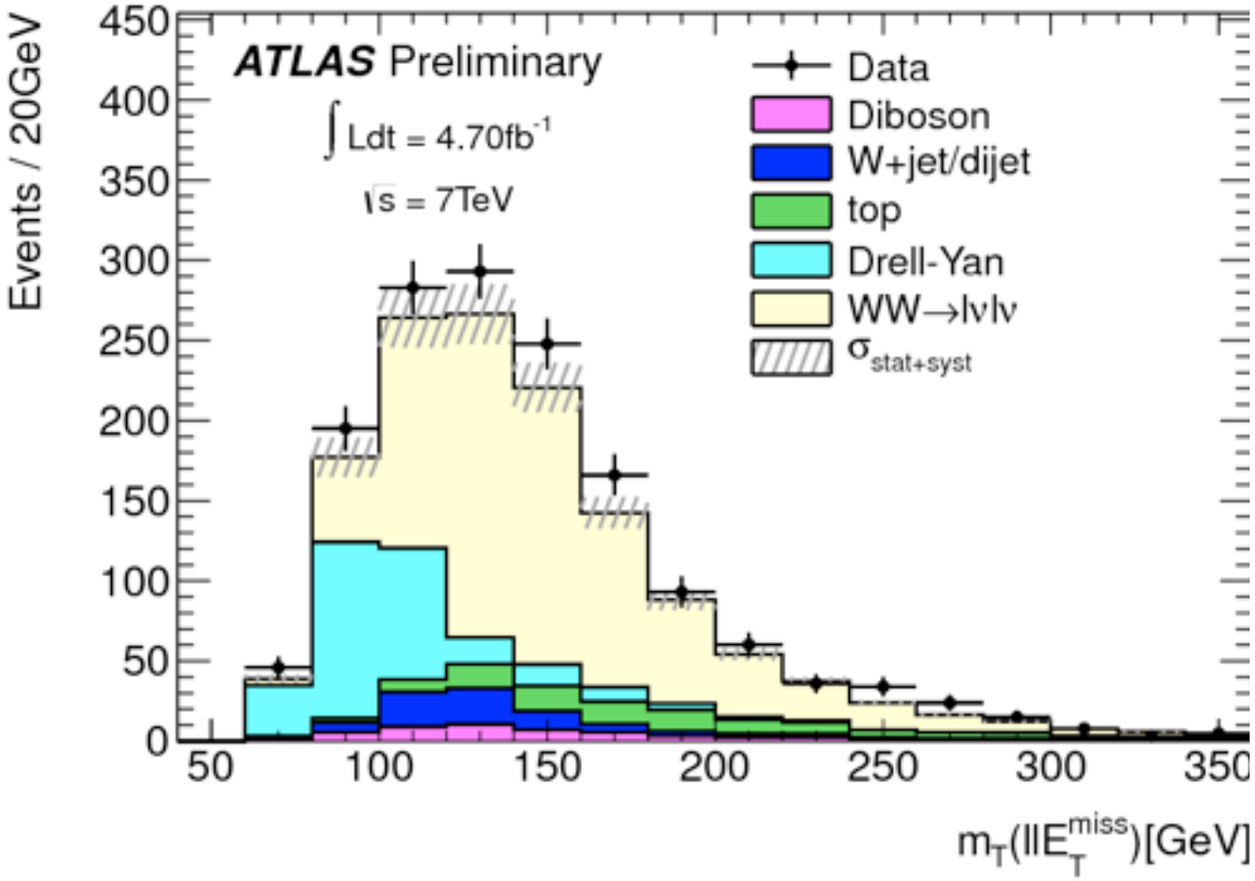
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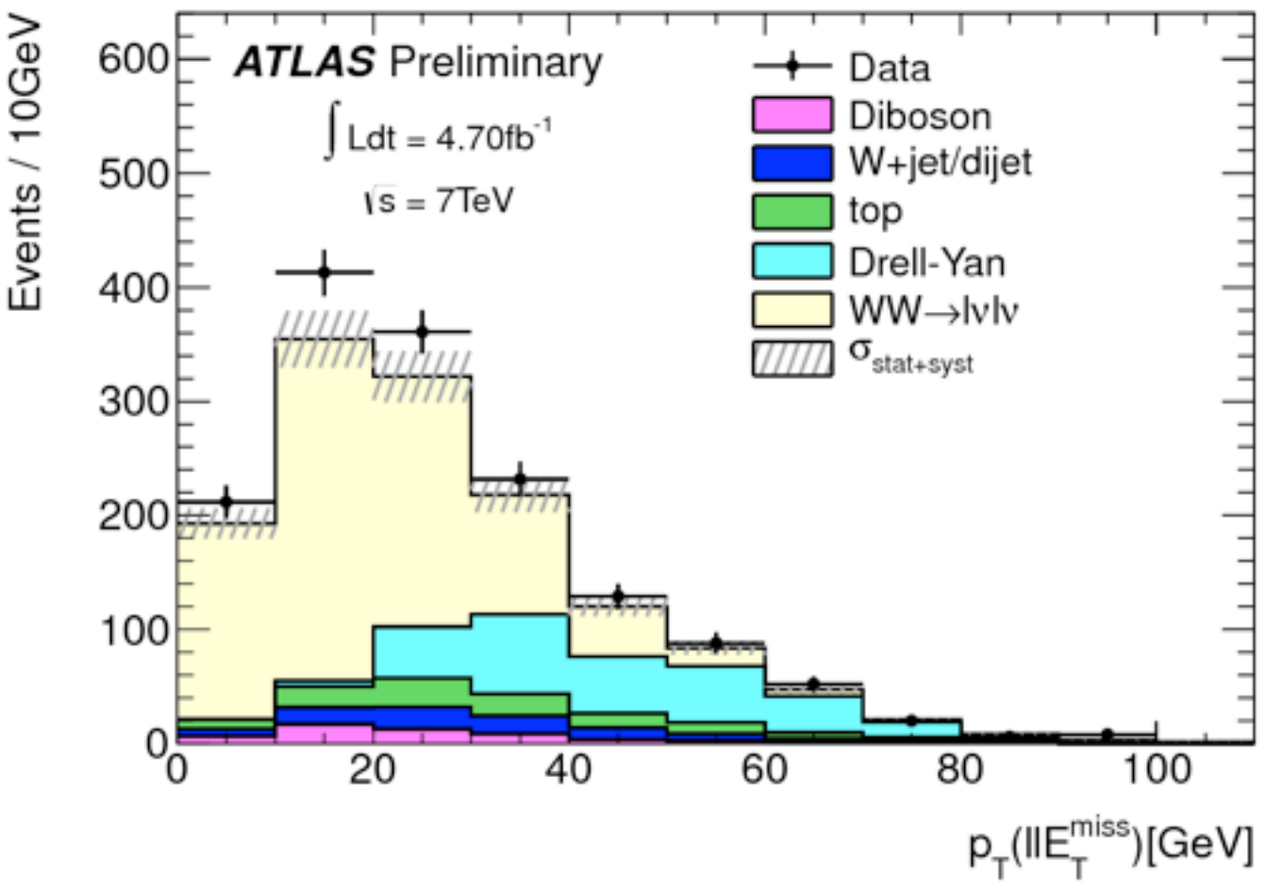
WW→lνlν
σstat+syst
Events / 20GeV
mT(llEmissT)[GeV]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UPDATED LHC-7

Measurement of W^+W^- production in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector and limits on anomalous WWZ and $WW\gamma$ couplings

The ATLAS Collaboration
(Dated: October 11, 2012)

This paper presents a measurement of the W^+W^- production cross section in pp collisions at $\sqrt{s} = 7$ TeV. The leptonic decay channels are analyzed using data corresponding to an integrated luminosity of 4.6 fb^{-1} collected with the ATLAS detector at the Large Hadron Collider. The W^+W^- production cross section $\sigma(pp \to W^+W^- + X)$ is measured to be 51.9 ± 2.0 (stat) ± 3.9 (syst) ± 2.0 (lumi) pb, compatible with the Standard Model prediction of $44.7\ ^{+2.1}_{-1.9}$ pb. A measurement of the normalized fiducial cross section as a function of the leading lepton transverse momentum is also presented. The reconstructed transverse momentum distribution of the leading lepton is used to extract limits on anomalous WWZ and $WW\gamma$ couplings.

Significance about the same as before

Additional pt(ll) cut

UPDATED LHC-

Measurement of W^+W^- production in pp collisions at $\sqrt{s} = 7$ T
detector and limits on anomalous WWZ and $WW\gamma$

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$\sqrt{s} = 7$ TeV. The leptonic decay channels are analyzed using data correspondin
luminosity of 4.6 fb^{-1} collected with the ATLAS detector at the Large Hadron Coll
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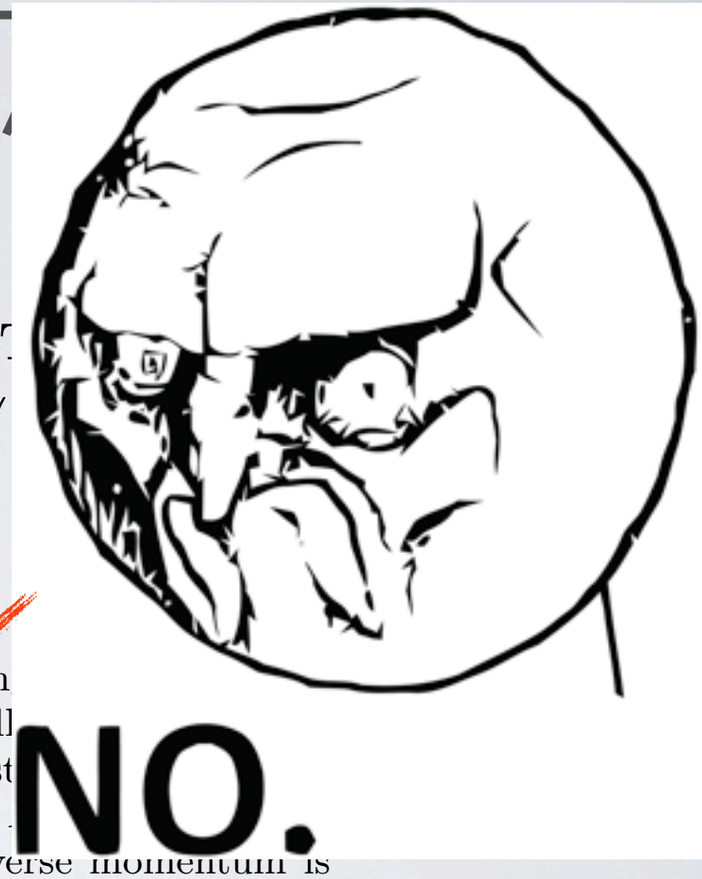

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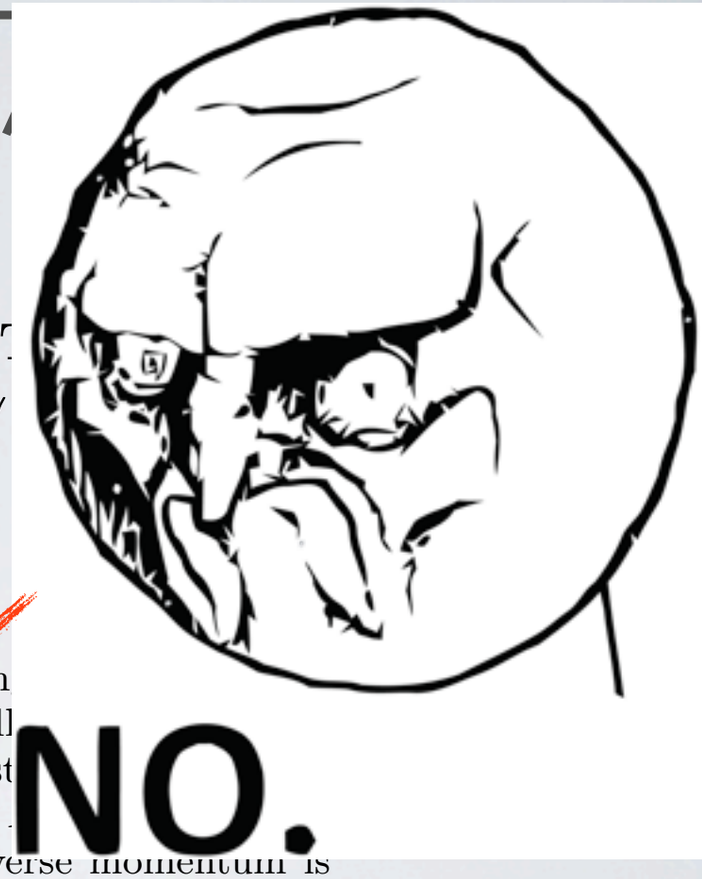


Three different SM cross sections @ 7 TeV have been given: 45.1, 47, 44.7

Better agreement needed on what to use

CMS 8 TEV 3.5/FB

WW→2ℓ2ν at 8 TeV: systematics & results

σ = 69.9 ± 2.8 (stat) ± 5.6 (sys) ± 3.1 (lum) pb

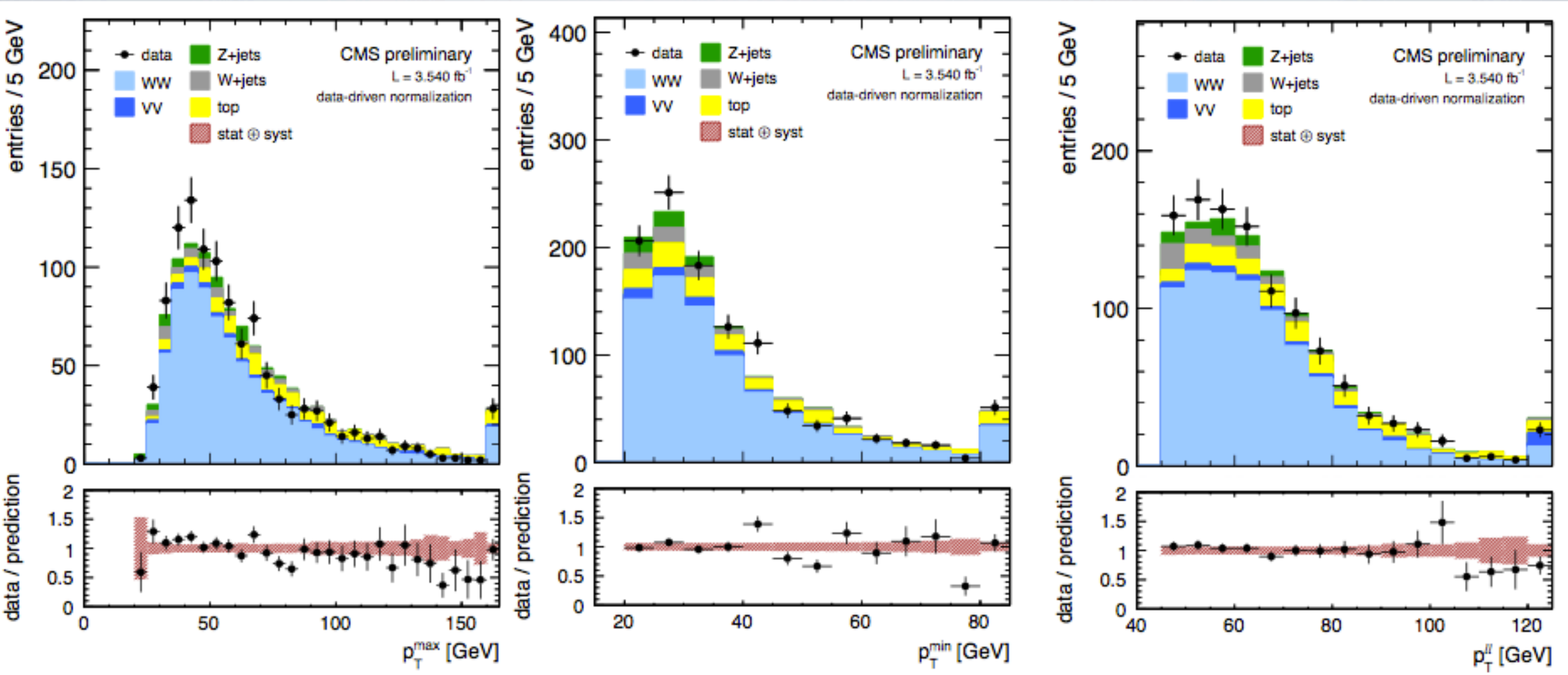
NLO prediction (MCFM): 57.25 ($^{+2.35}_{-1.60}$) pb

- **Already 4% statistical precision**
- **About 1.8σ higher than the NLO prediction**

It grows at 8 TeV even faster!

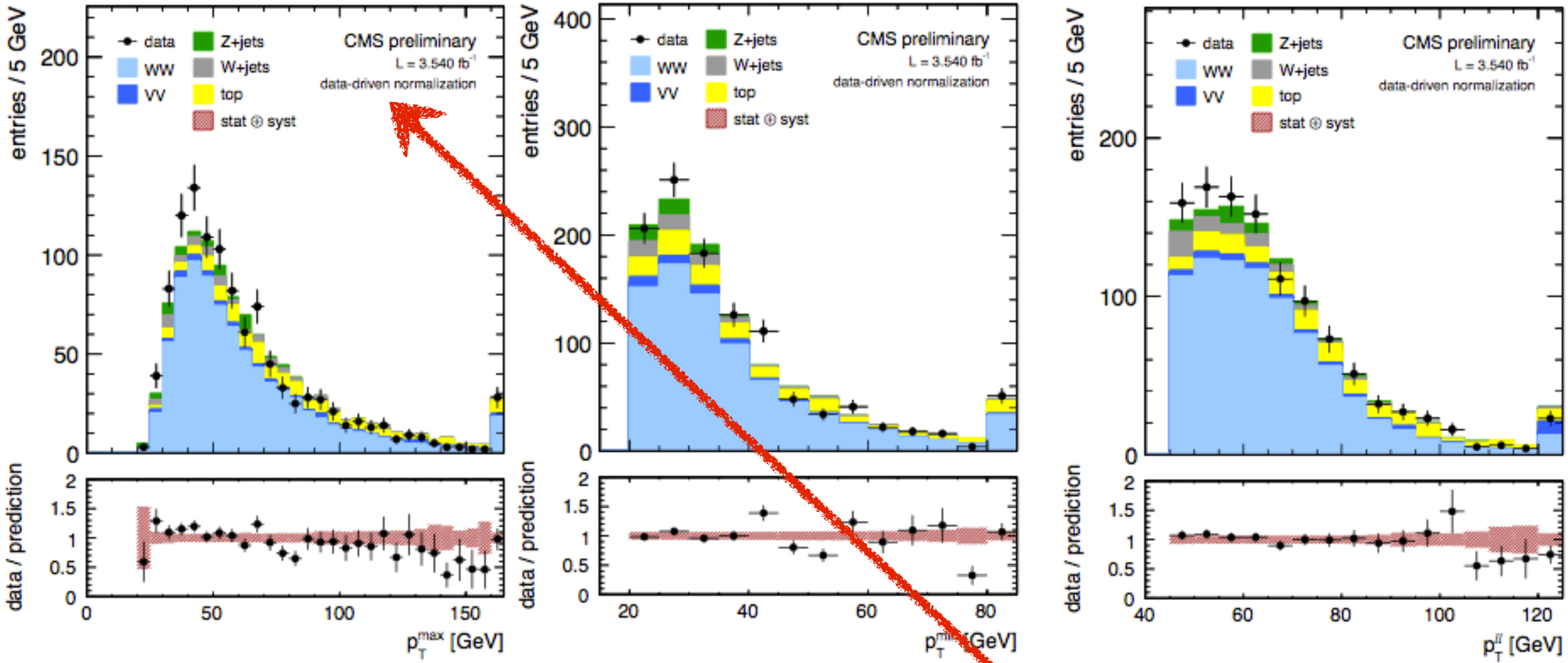
$$\left.\frac{\sigma(8)}{\sigma(7)}\right|_{\rm th} = 1.21 \qquad \left.\frac{\sigma(8)}{\sigma(7)}\right|_{\rm exp} = 1.33$$

CMS8



Looks pretty good...

CMS8



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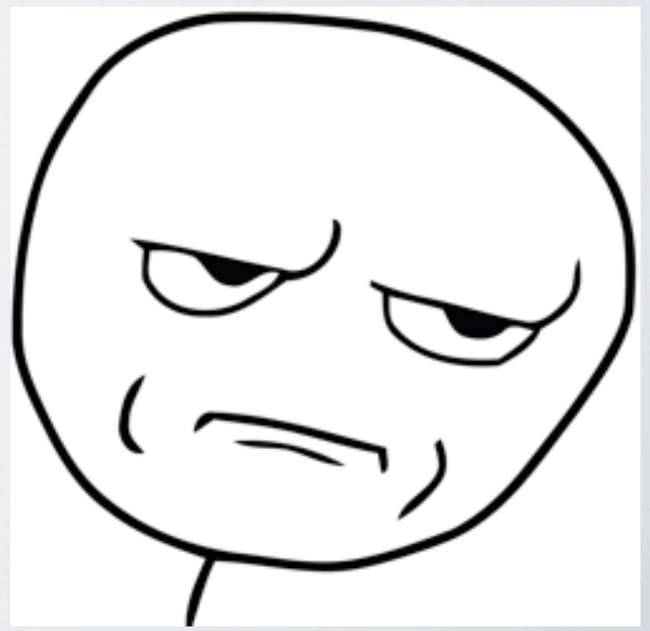
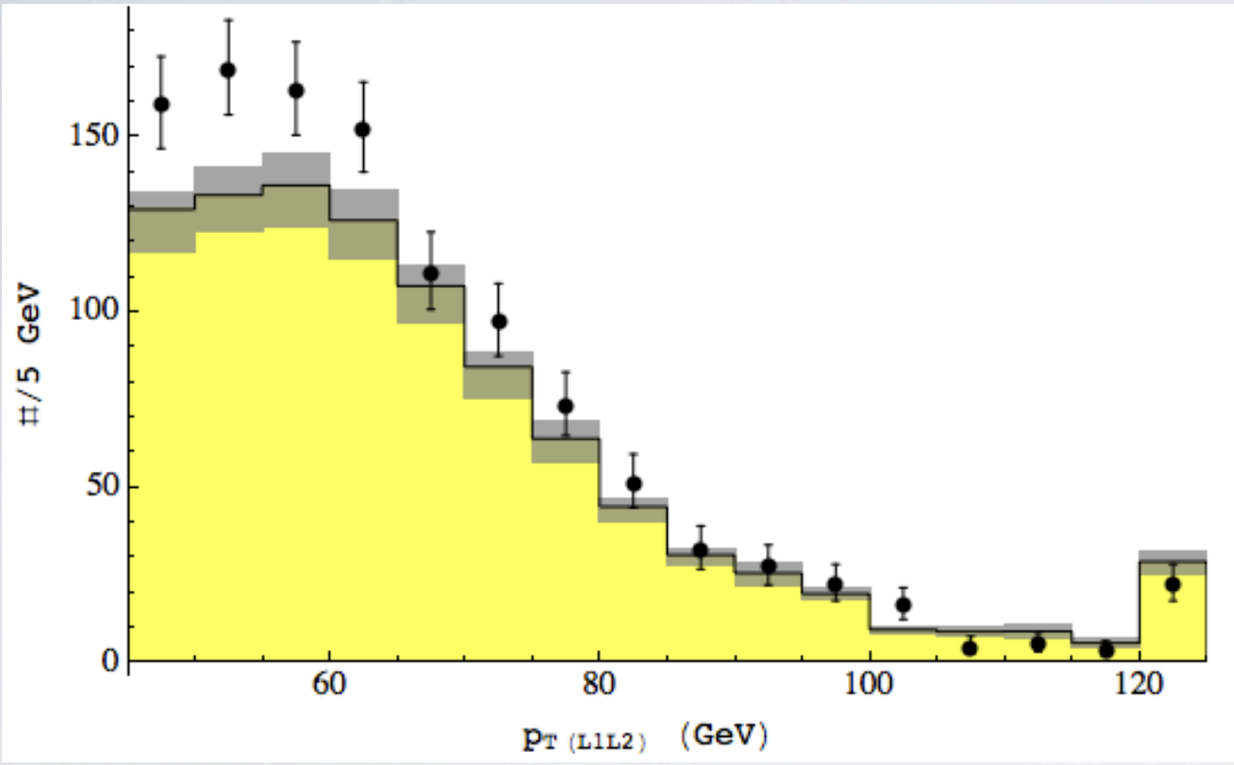
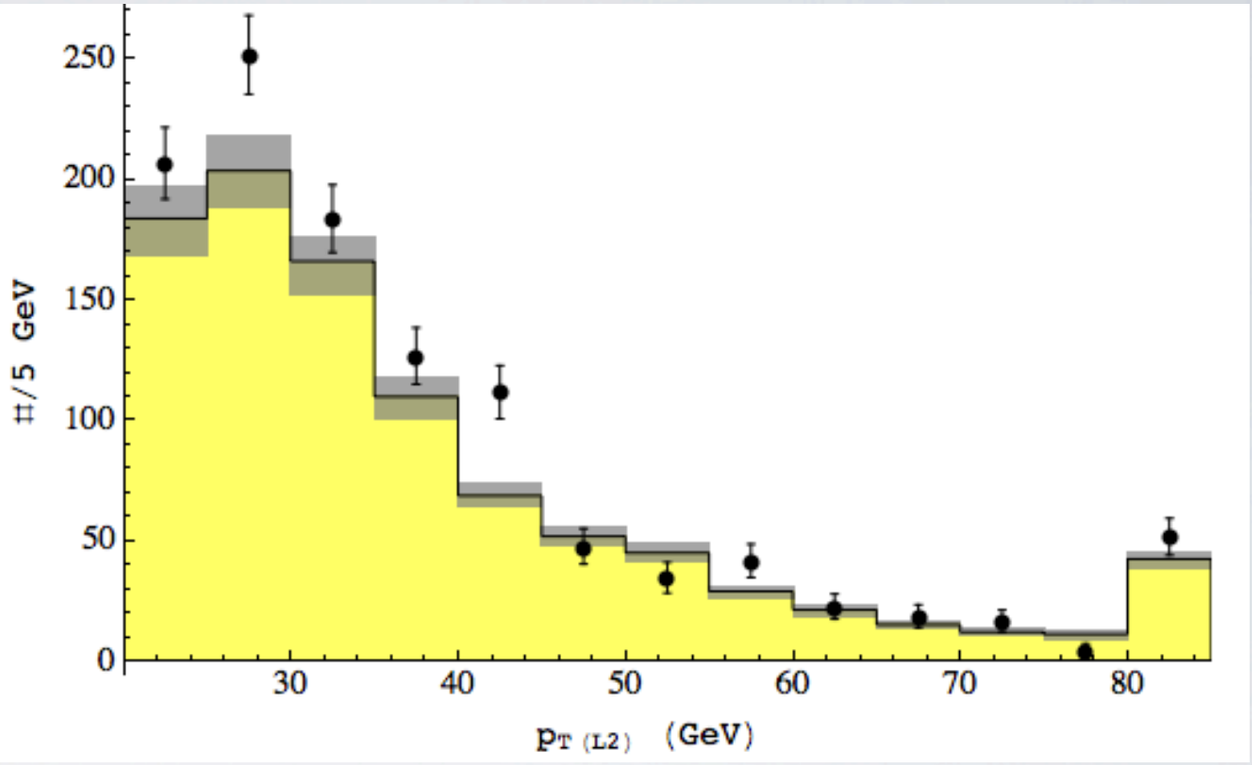
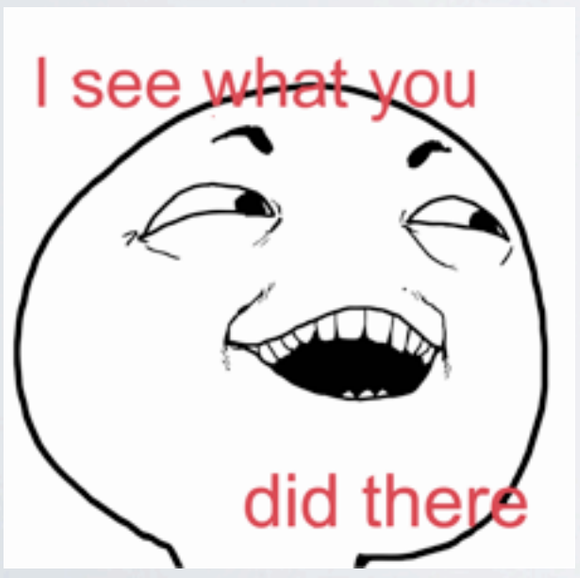
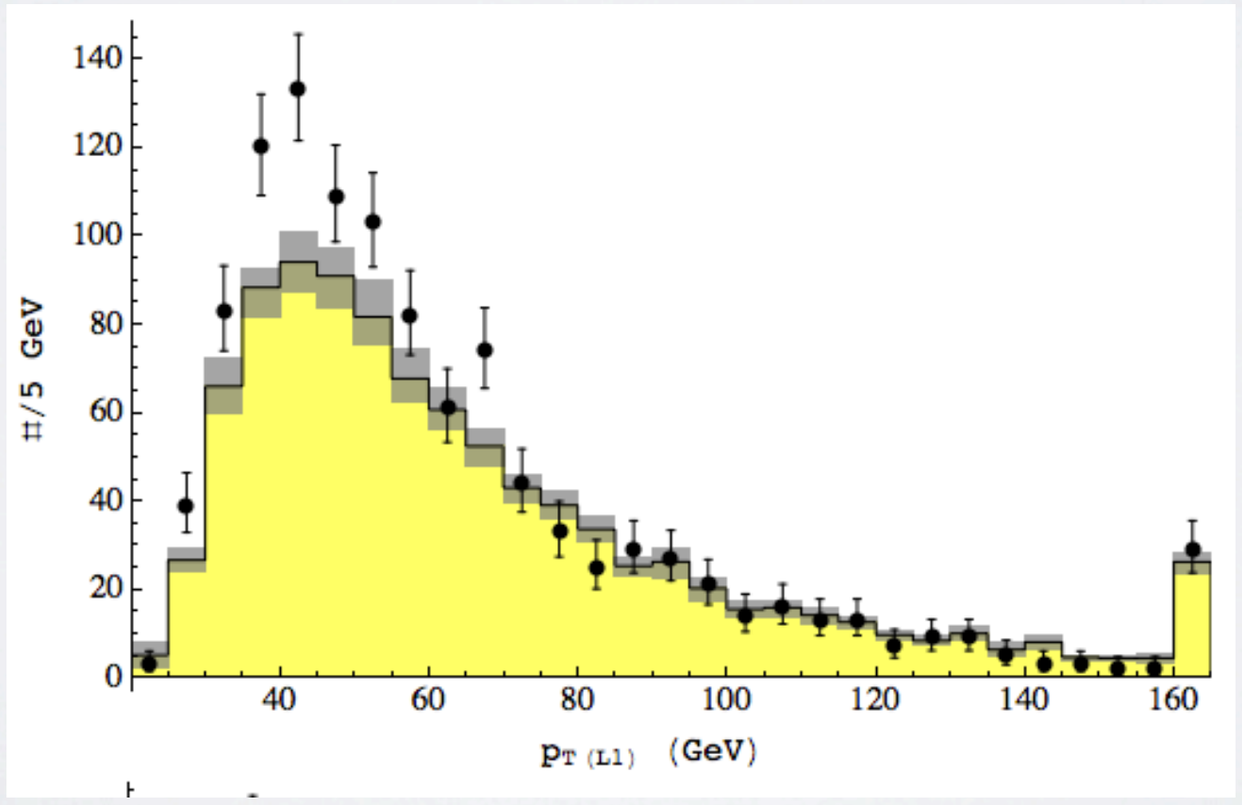


NO EXTRA NORMALIZATION...





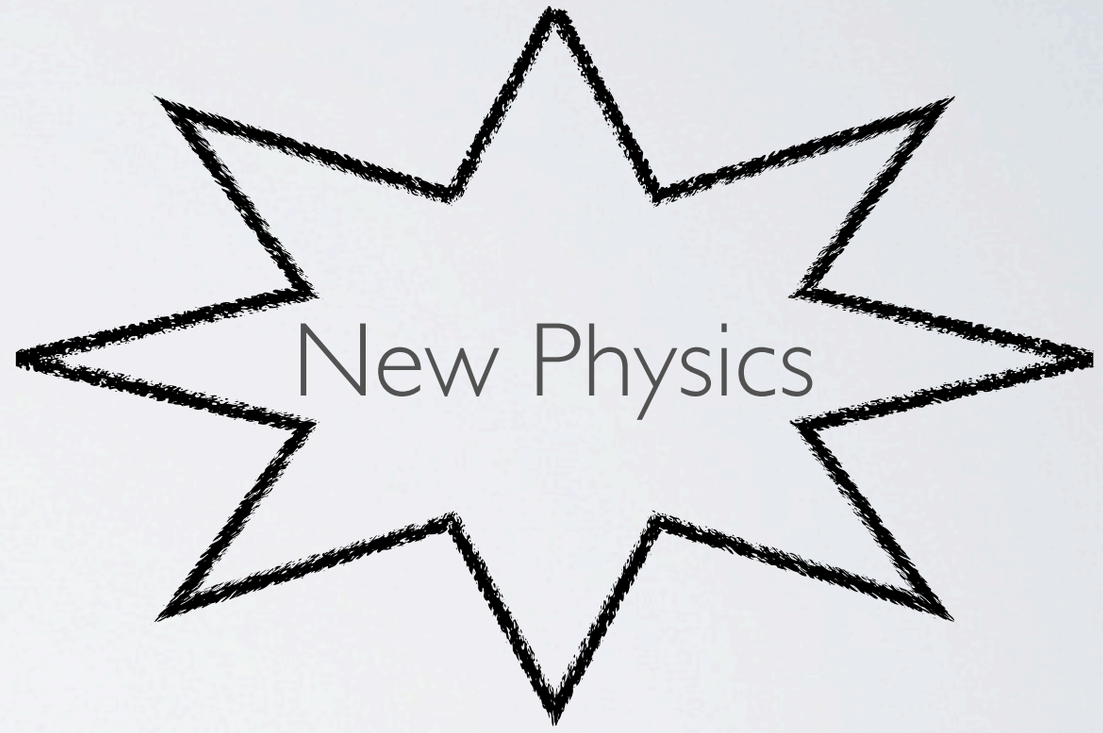




Upward fluctuations in all measurements ***or*** a trend?

Two roads diverged in a yellow wood,
and sorry I could not travel both...

SM calculation
wrong



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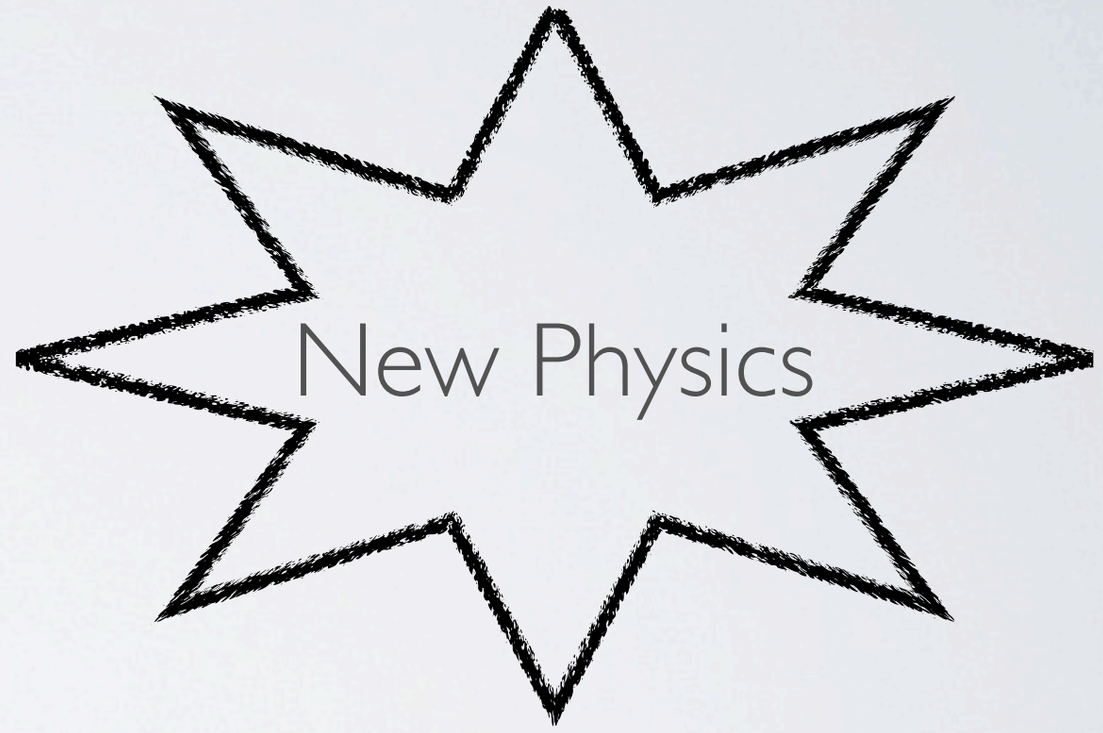


Will come back to the less traveled one
and that of course may make all the difference...

INGREDIENTS FOR BSM EXPLANATION

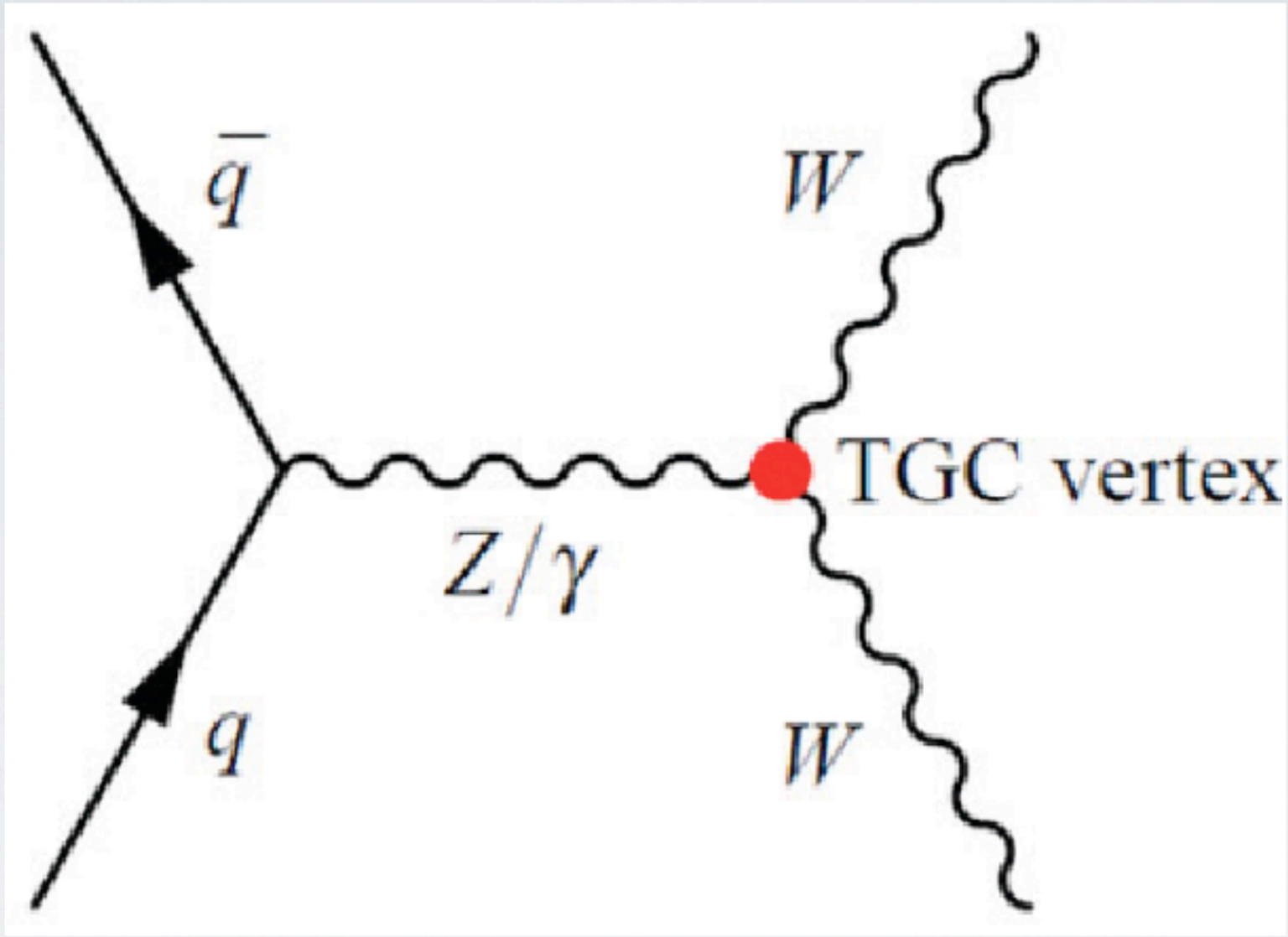
- ATLAS and CMS both measure OS dileptons + MET **with** a jet VETO

- Final state needs to be OS leptons+MET with *nothing* else essentially

- Does ***NOT*** imply there have to be ***REAL W's***

  - Doesn't hurt either if there are!

AN EXPLANATION?



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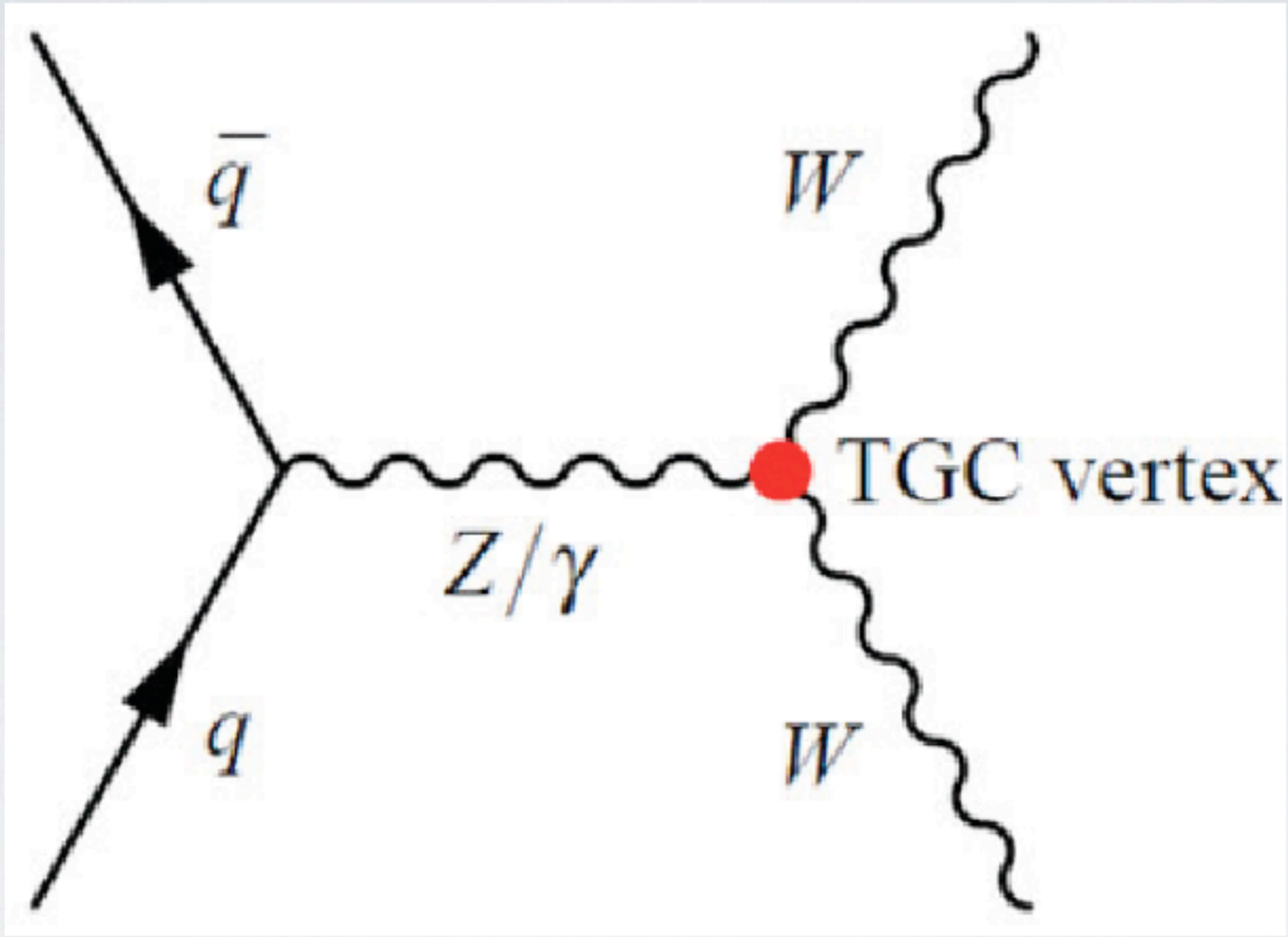

NO!

NEW PHYSICS EXPLANATION

- Measurement is 2 leptons + MET so we need this... (jet veto)
- Kinematics ***similar*** to WW of SM
- Need a cross section of a few pb to make a difference

What does all this and more? EW GAUGINOS!!

WAIT ISN'T SUSY DEAD OR "IN THE HOSPITAL" OR SOMETHING?

Popular physics theory running out of hiding places

By Pallab Ghosh
Science correspondent, BBC News

Researchers at the Large Hadron Collider have detected one of the rarest particle decays seen in nature.

The finding deals a significant blow to the theory of physics known as supersymmetry.

Many researchers had hoped the LHC would have confirmed this by now.

Supersymmetry, or Susy, has gained popularity as a way to explain some of the inconsistencies in the traditional theory of subatomic physics known as the Standard Model.

Supersymmetry predicts heavy versions of all the particles we know about - "super particles"

The new observation, reported at the **Hadron Collider Physics conference in Kyoto** and outlined in **an as-yet unpublished paper**, is not consistent with many of the most likely models of Susy.

Prof Chris Parkes, who is the spokesperson for the UK participation in the LHCb experiment, told BBC News: "Supersymmetry may not be dead but these latest results have certainly put it into hospital."

Related Stories

LHC puts supersymmetry in doubt

Higgs results 'get even stronger'

Higgs-like particle 'discovered'

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Popular physics theory running out of

Of Particular Significance

Conversations About Science with Theoretical Physicist Matt Strassler

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FIRST TIME VISITOR?

This site (new and still growing rapidly) will eventually cover many topics in science, but currently focuses on particle physics in particular. My aim is to serve the public, including those with no background knowledge of physics, but also those who have been keeping track of the latest in particle physics news. If you're not yourself an expert, you might want to click on "New? Start Here" or "About" to get started.

← Summary of New Higgs Results

Remember That "Blow" to Supersymmetry (And Other Theories)? →

Why Theories Don't Go Into Hospitals

Posted on November 14, 2012 | 70 Comments

I'm always amused at how very reasonable remarks so often generate attacks from unreasonable people. I wrote a perfectly ordinary post about what one does and doesn't learn from LHCb's important new measurement at the Large

'discovered'

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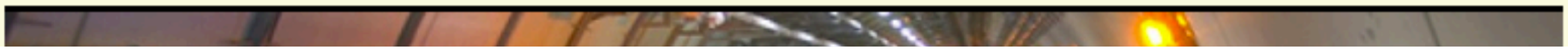

No Deeper Commentary Intended...

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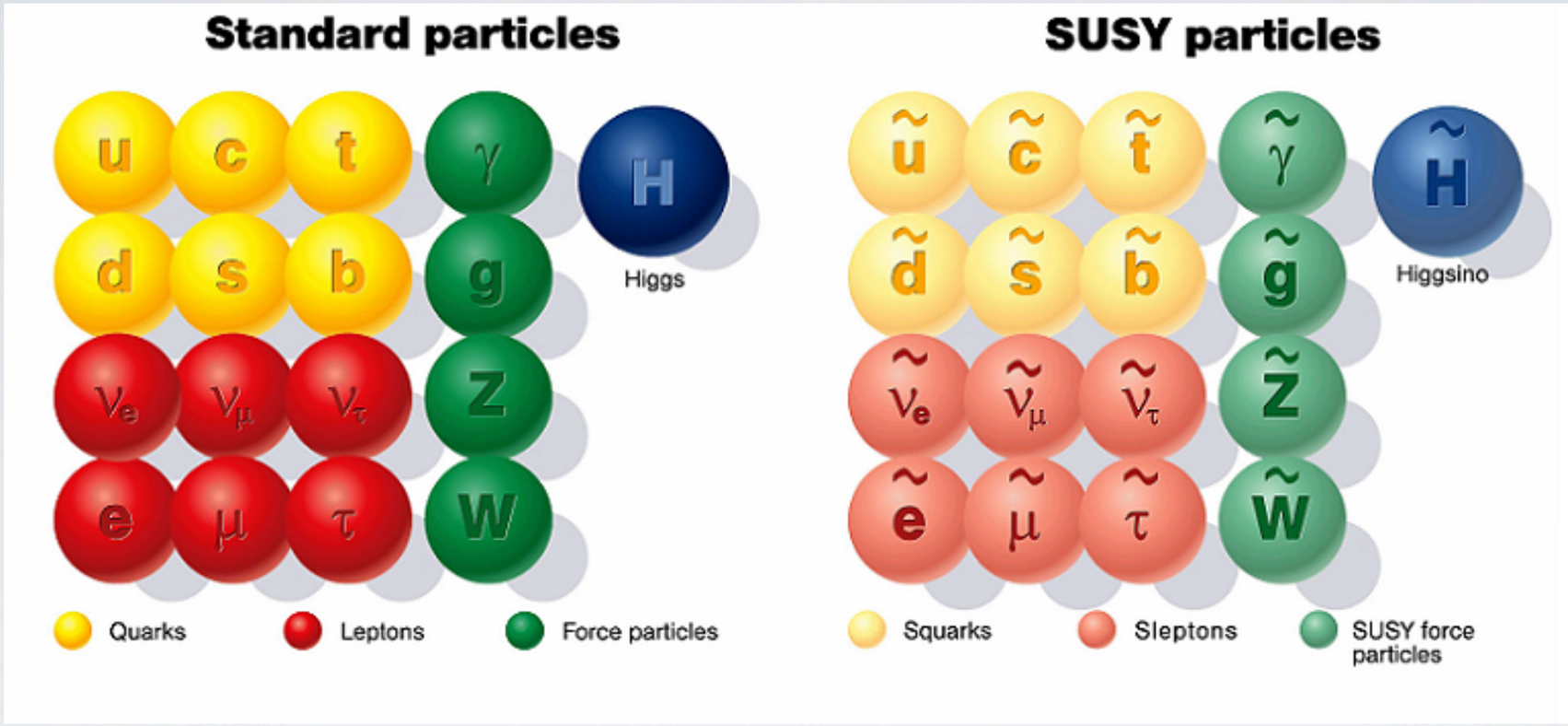
SUSY??



We've found ALMOST half of the particles...

SUSY (MET) PRE LHC

300 GeV - colored (Tevatron) sparticles

100 GeV (LEP) EW States

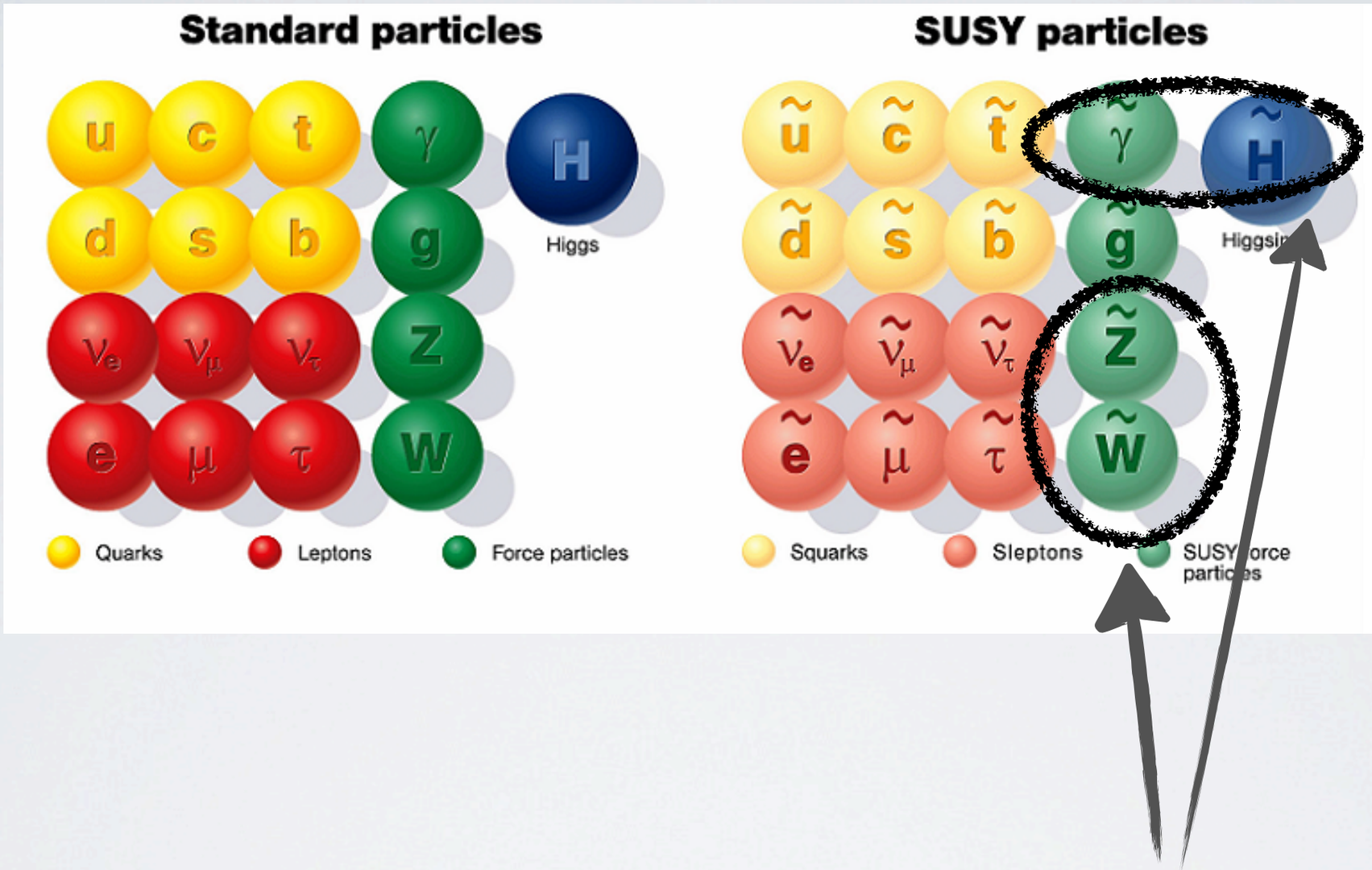
SUSY (MET) LHC

1000 GeV - colored (Tevatron) sparticles

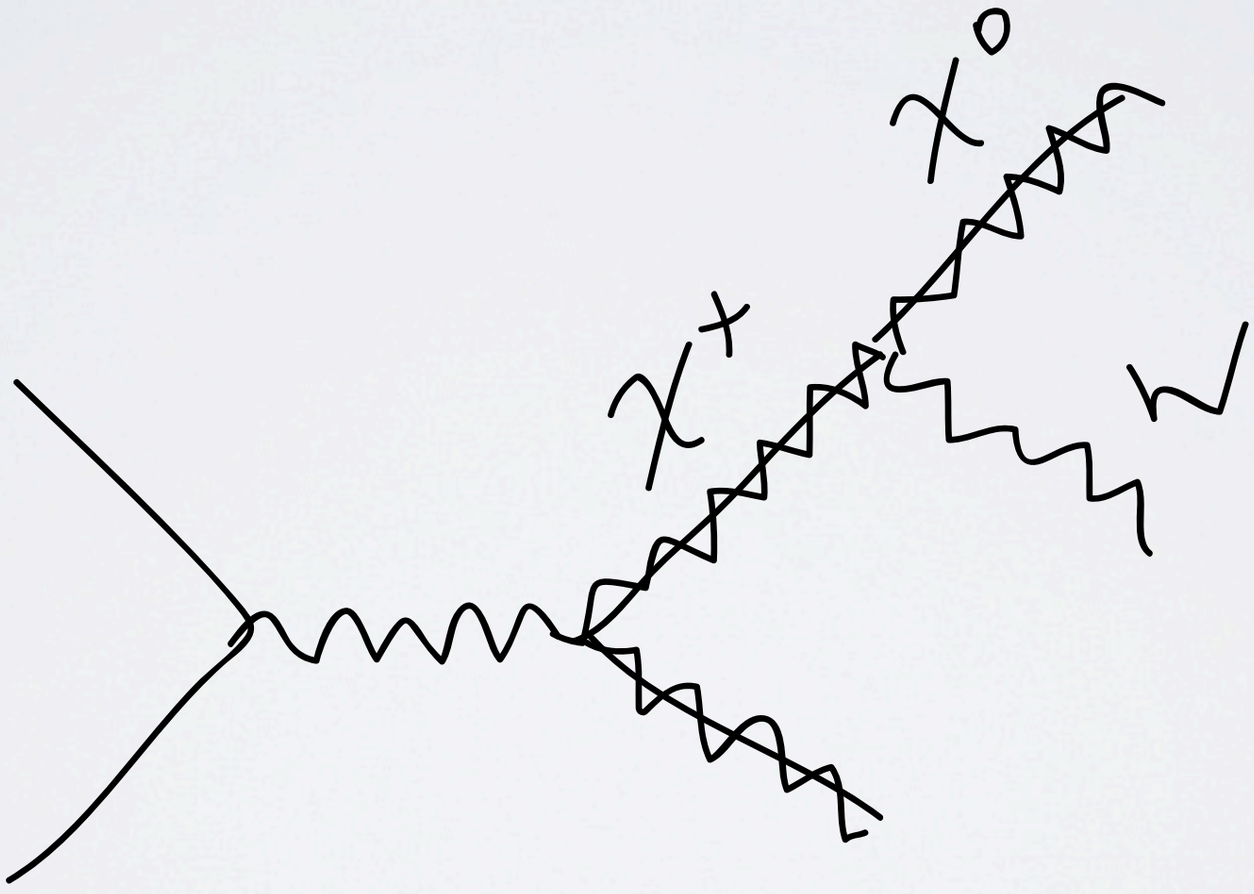
100 GeV (LEP) EW States

Just starting to enter into EW game

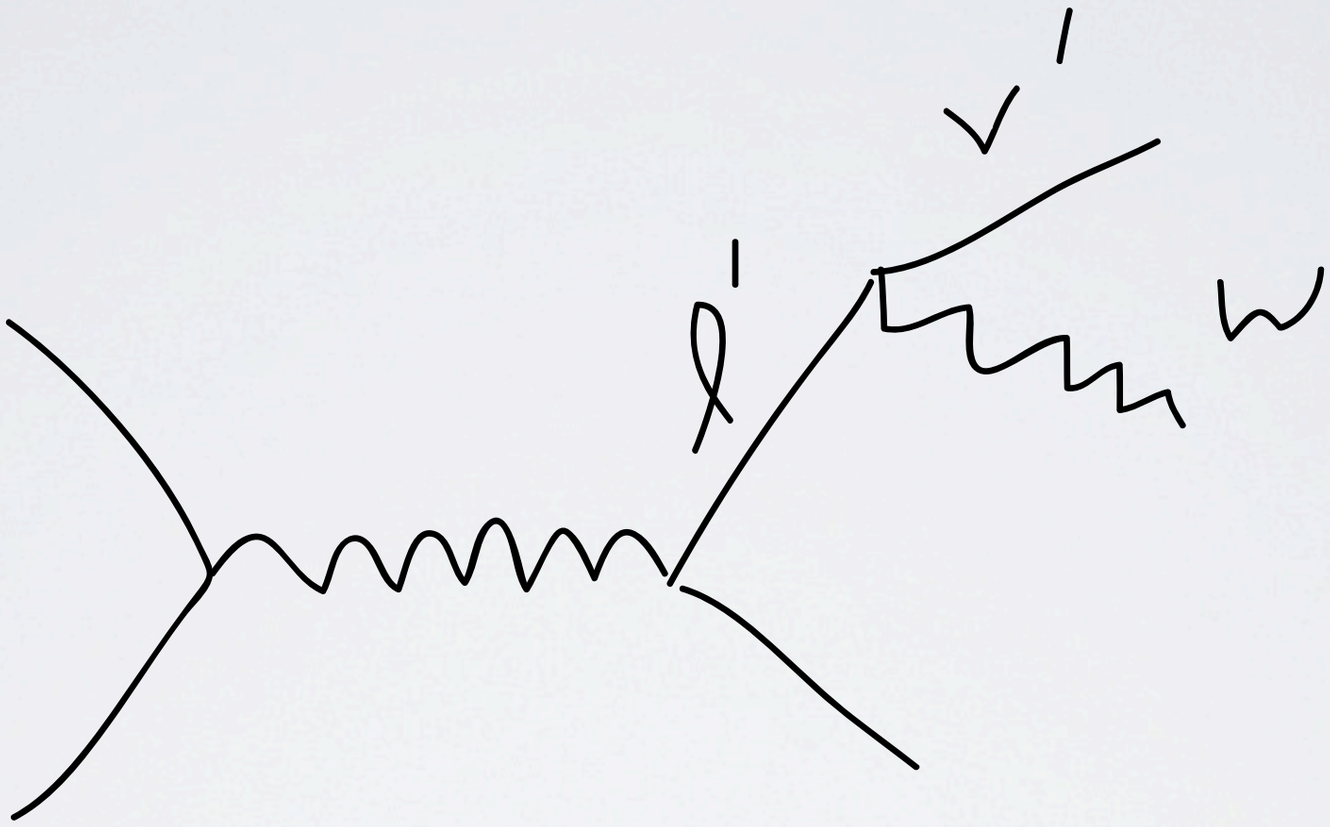
SUSY??


Standard particles
u c t γ
d s b g
νe νμ ντ Z
e μ τ W
H
Higgs
Quarks
Leptons
Force particles
SUSY particles
ũ c̃ t̃ γ̃
d̃ s̃ b̃ g̃
ν̃e ν̃μ ν̃τ Z̃
ẽ μ̃ τ̃ W̃
H̃
Squarks
Sleptons
Focus here

EXAMPLE TOPOLOGIES FOR WW+MET

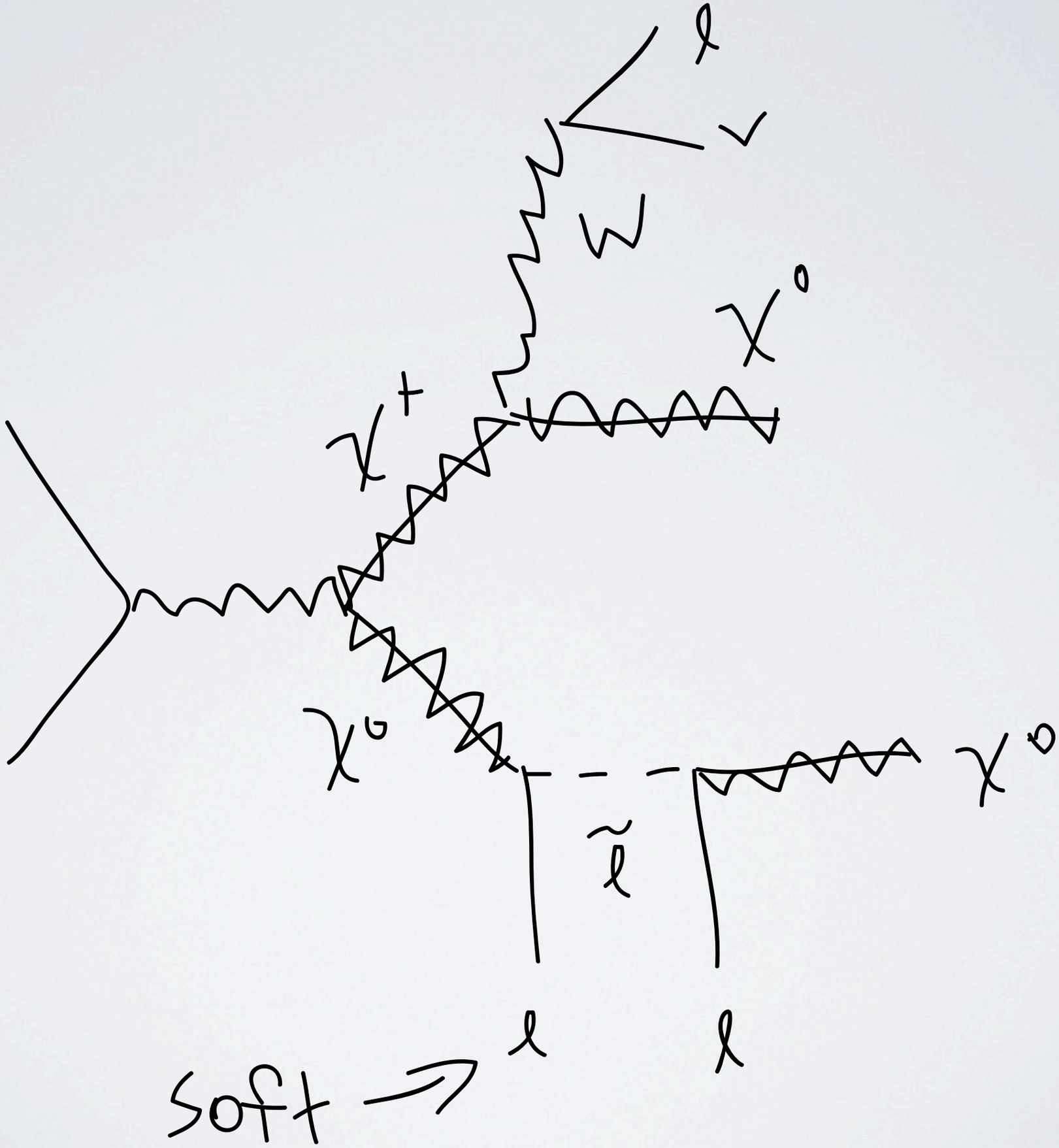


DON'T LIKE SUSY??



"Heavy Lepton"

SUSY HAS OTHER OPTIONS



GRAVITY SPECTRUM

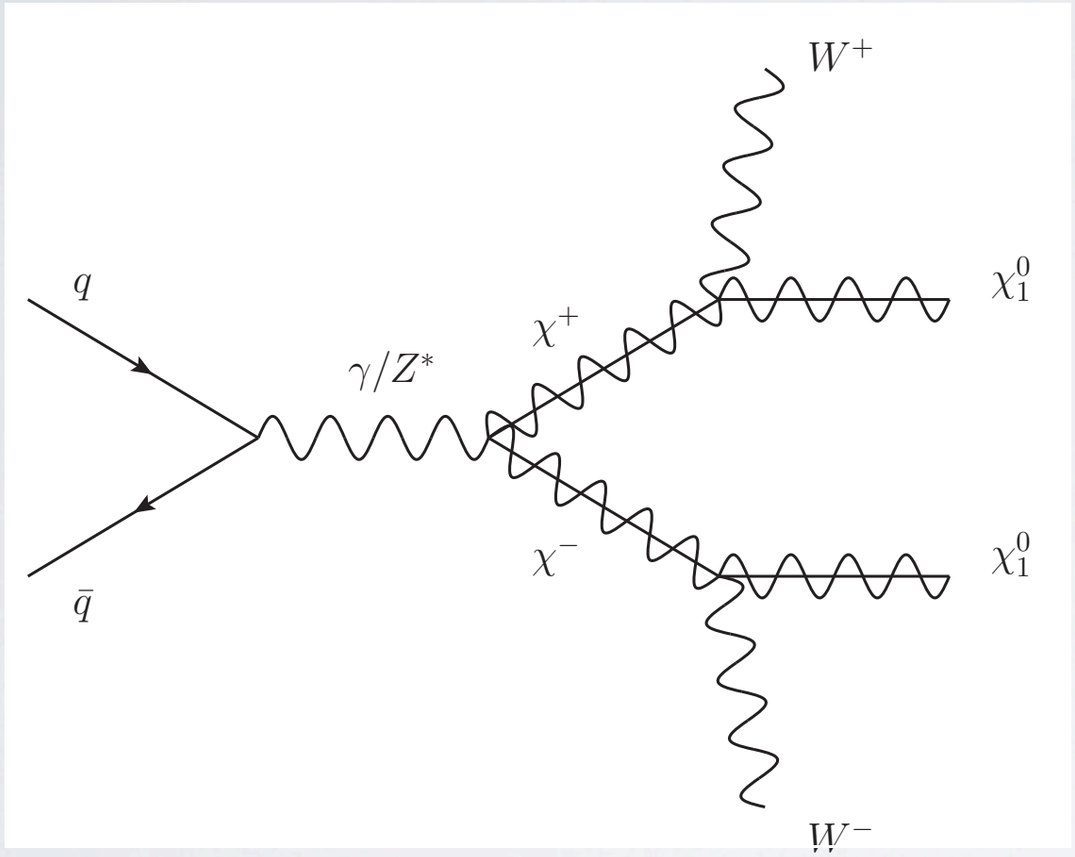
——— $\chi_1^\pm, \chi_2^0$ O(100 GeV)

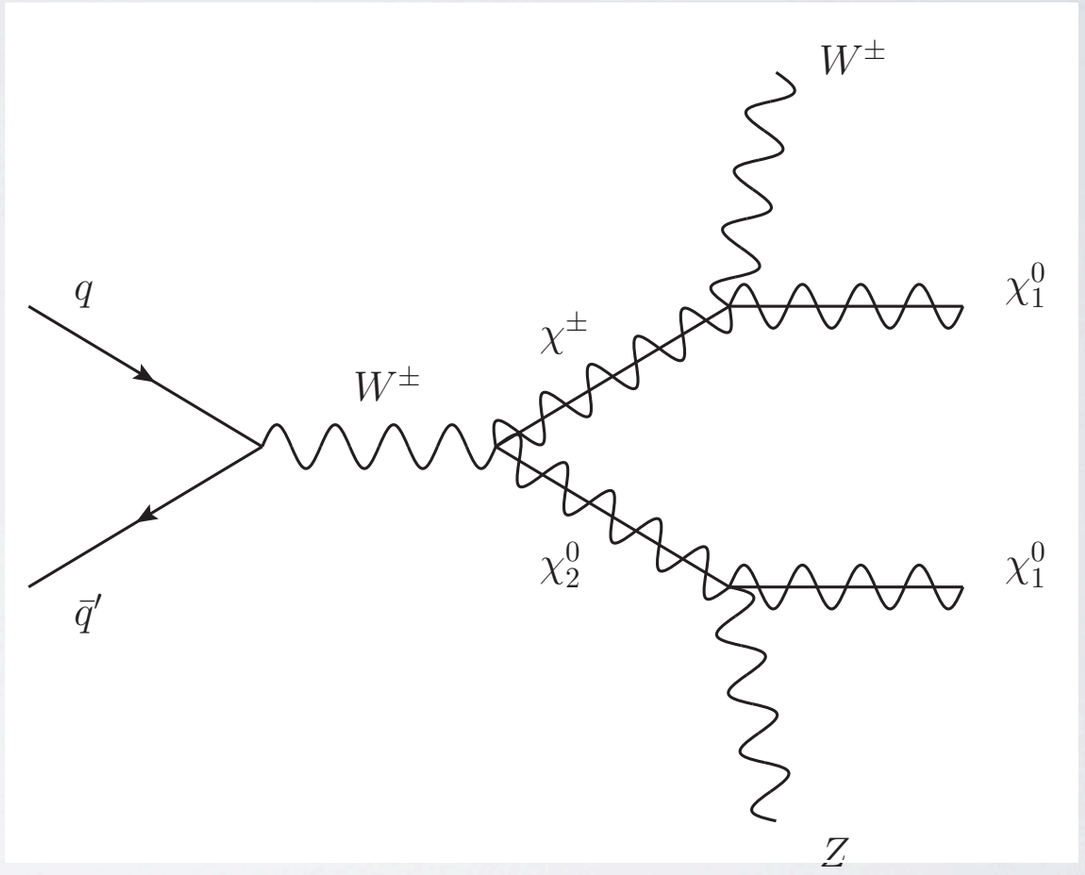
Could be at LEP limit!

Amusingly the right point
to affect the cross section significantly...

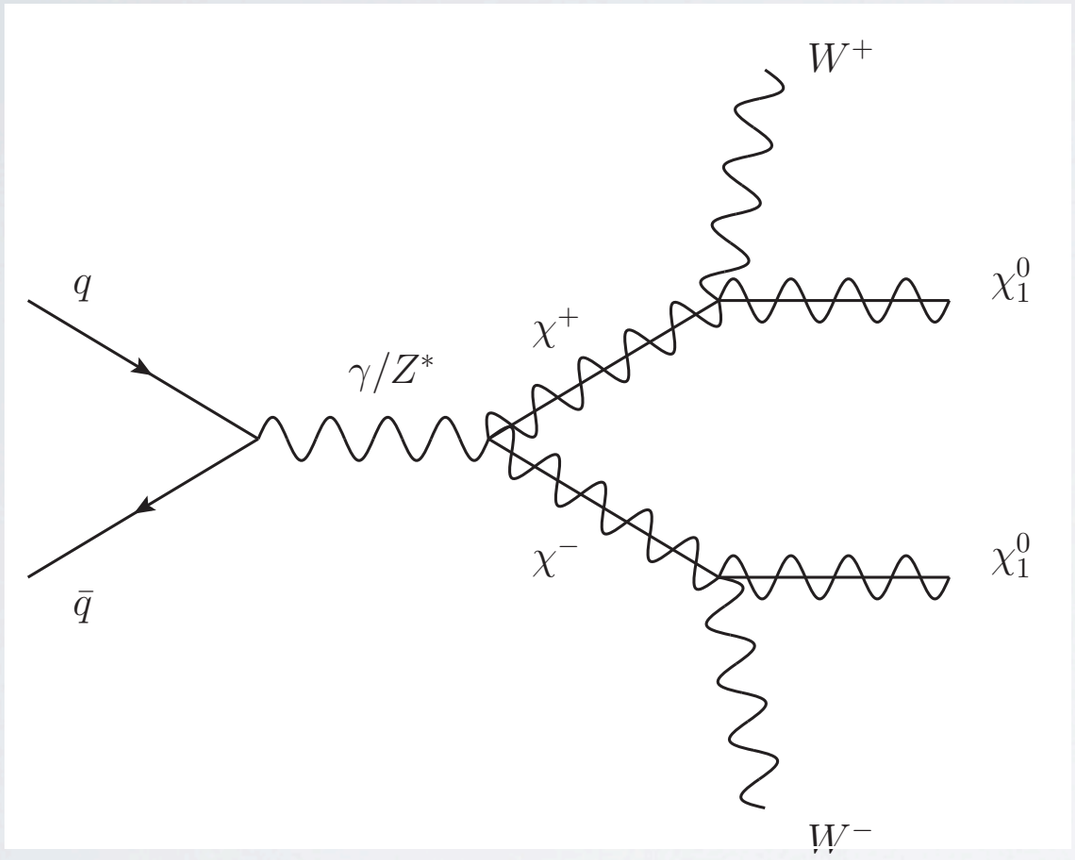
——— χ_1^0 O(GeV)

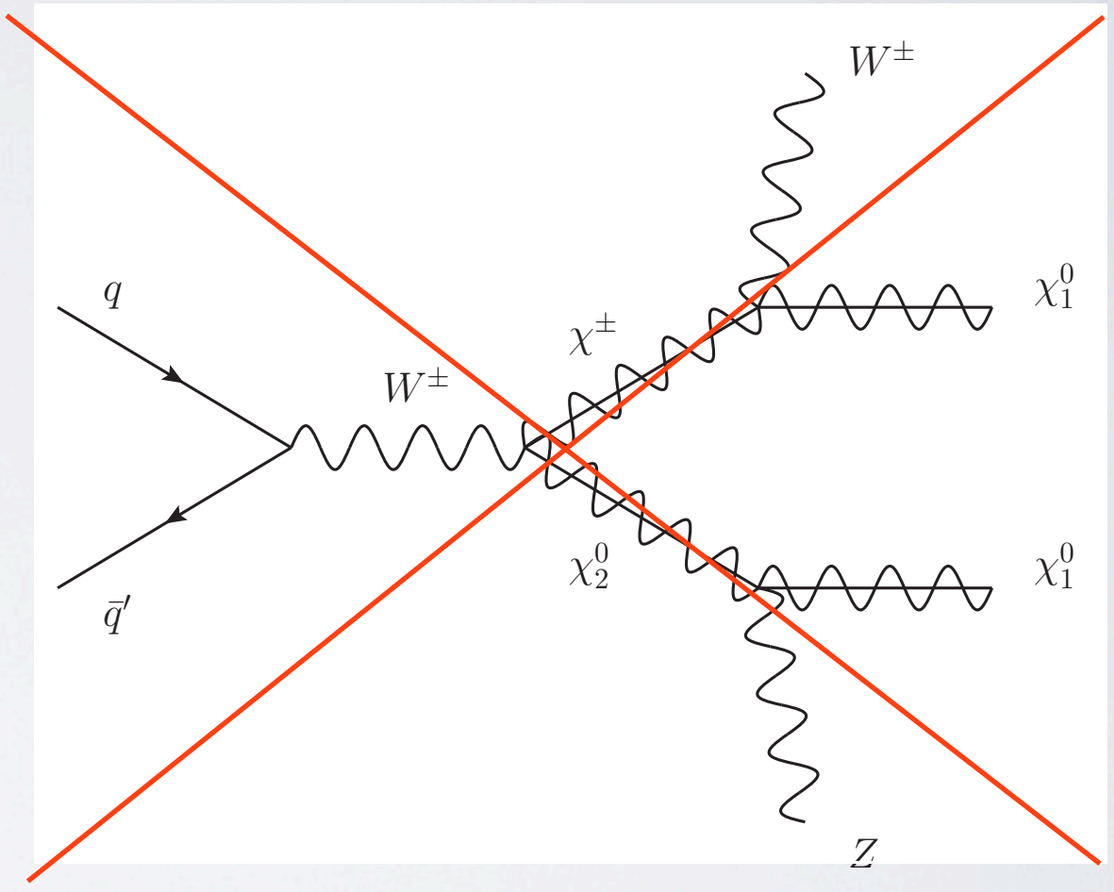
EXAMPLE TOPOLOGIES





EXAMPLE TOPOLOGIES

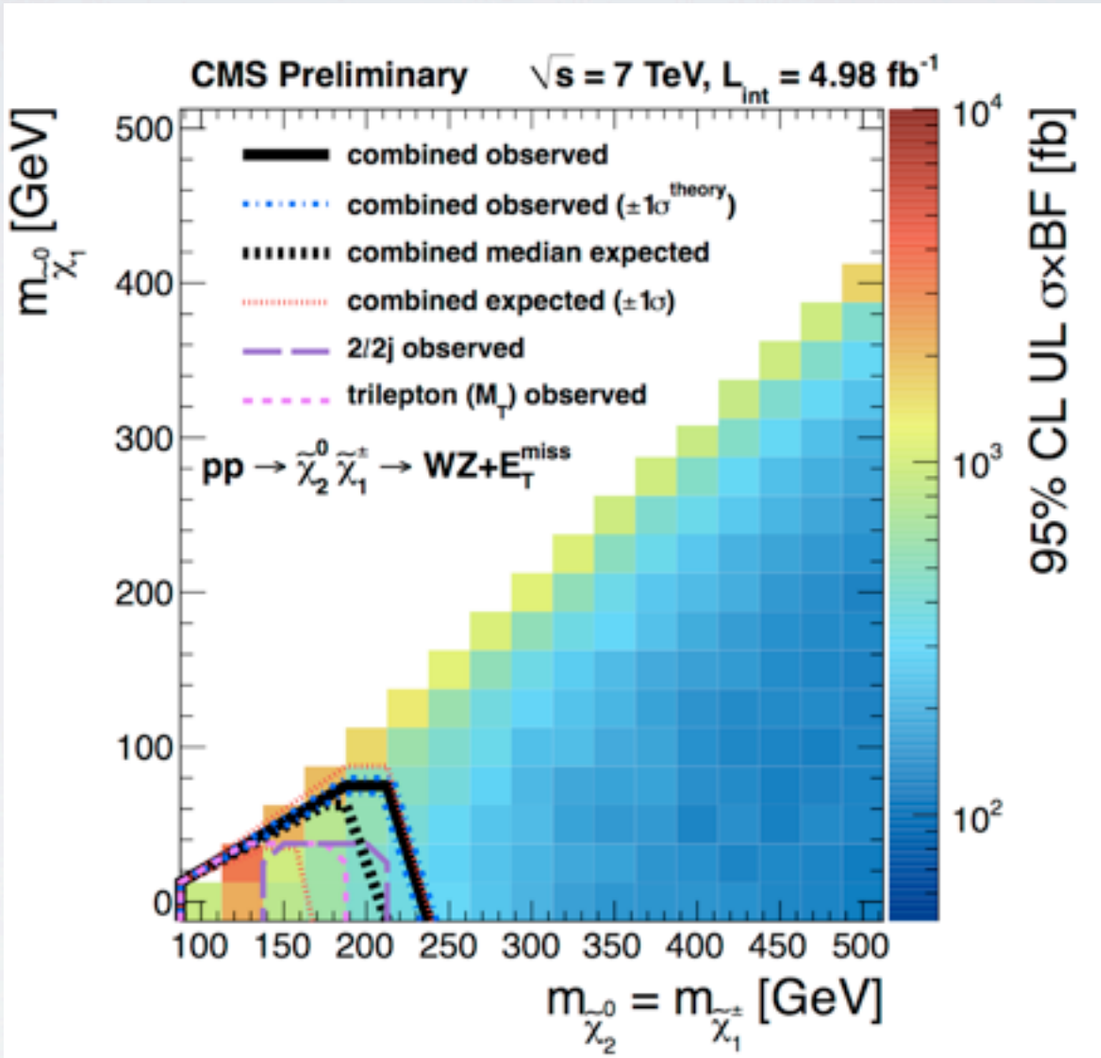




Tied for second most interesting result of summer

EW GAUGINO BOUNDS

WZ final state ruled out well above LEP



Wh state also ruled out by ATLAS 7 TeV Wh search

~ 160 GeV Higgsinos

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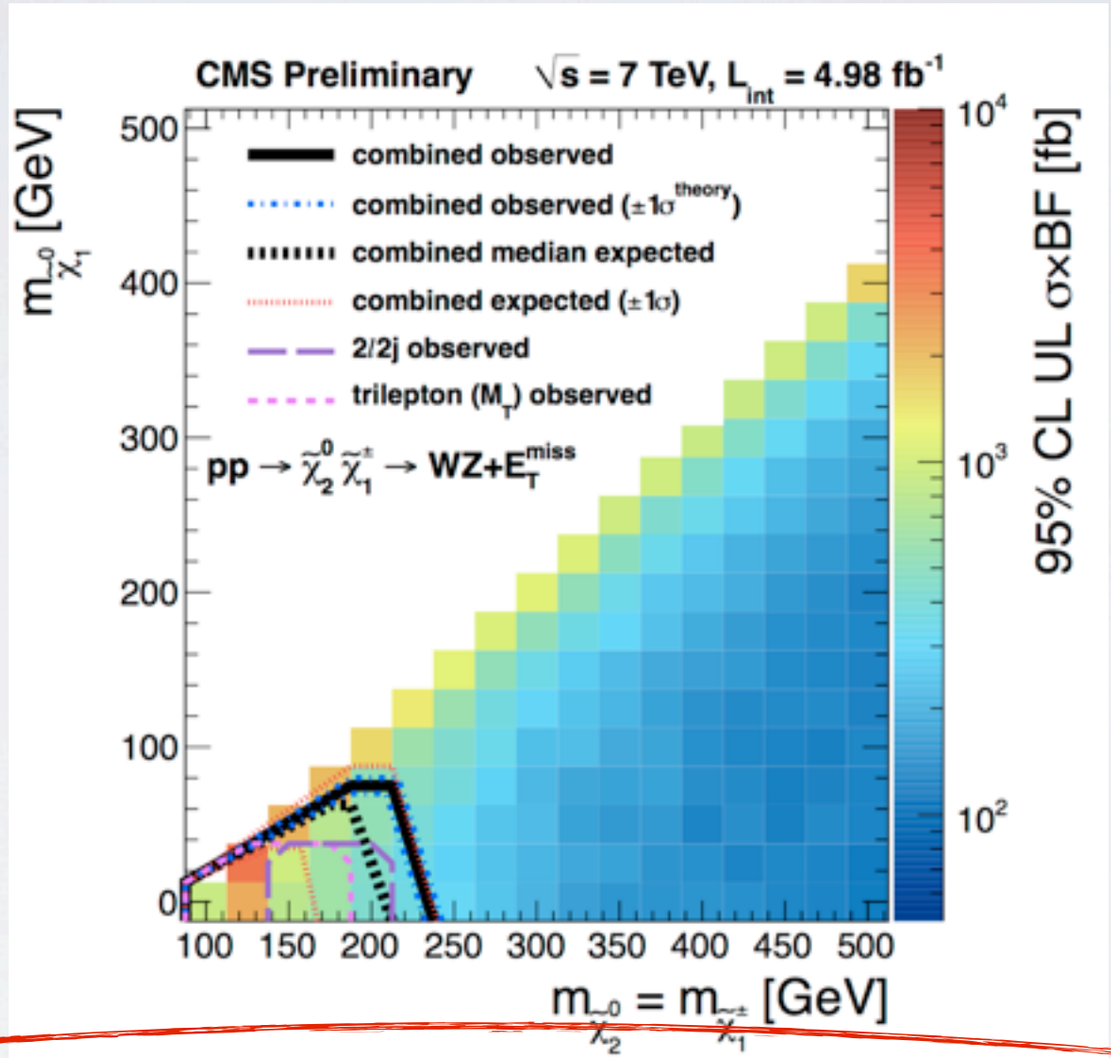
WZ final state ruled out well above LEP



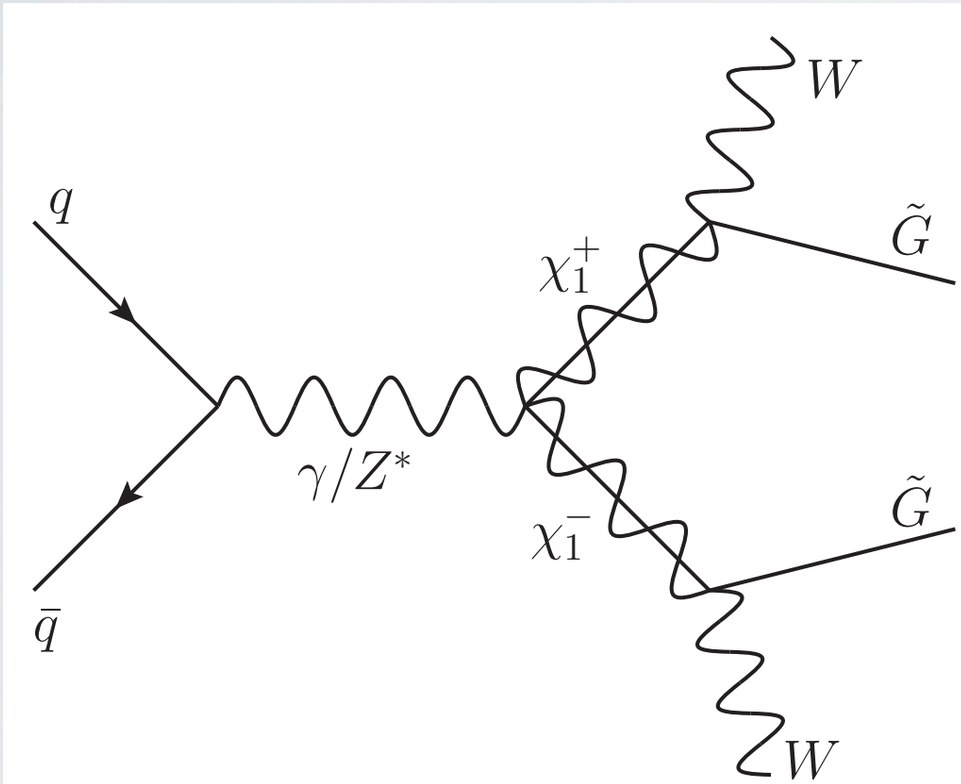
Wh state also ruled out by ATLAS 7 TeV Wh search

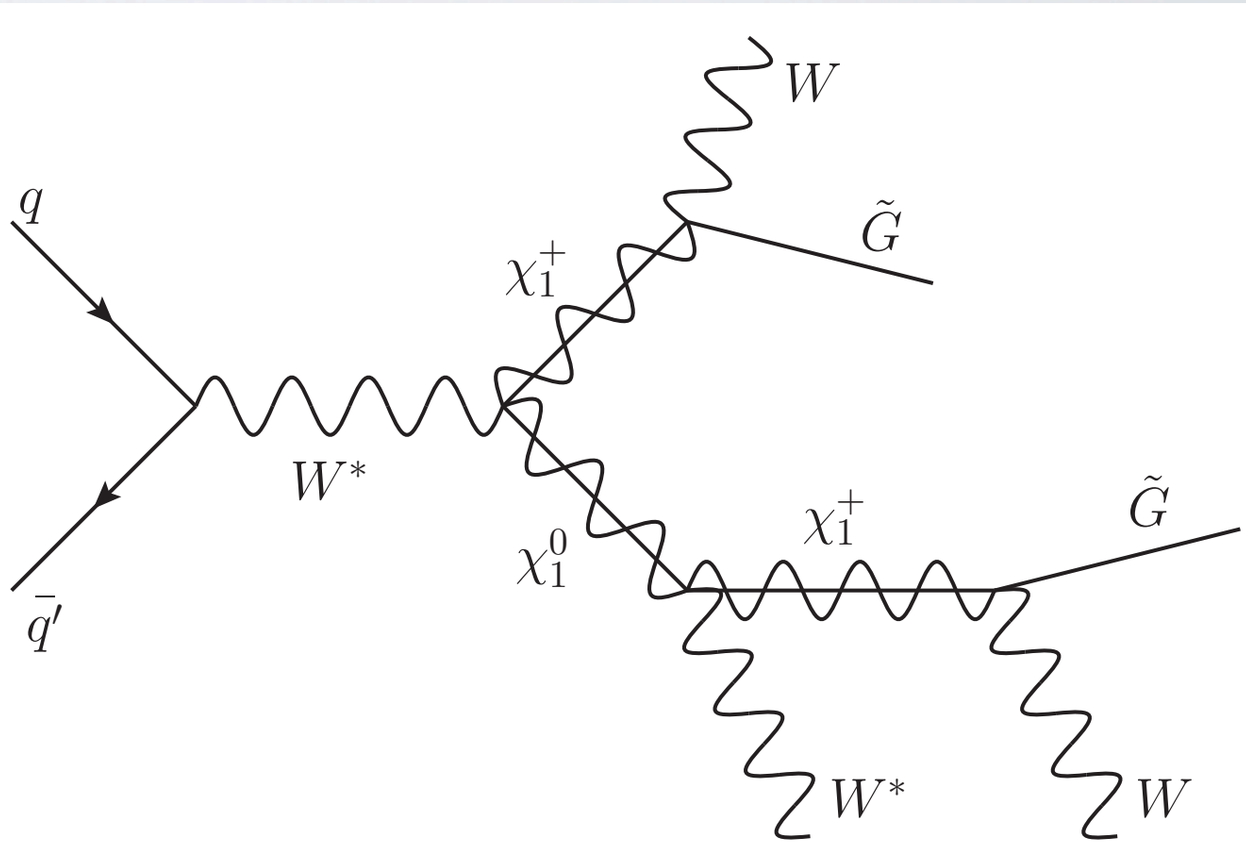
~ 160 GeV Higgsinos **1206.6888**

(ours not ATLAS)

ARE THERE WAYS OUT? WW WITHOUT WH AND WZ??

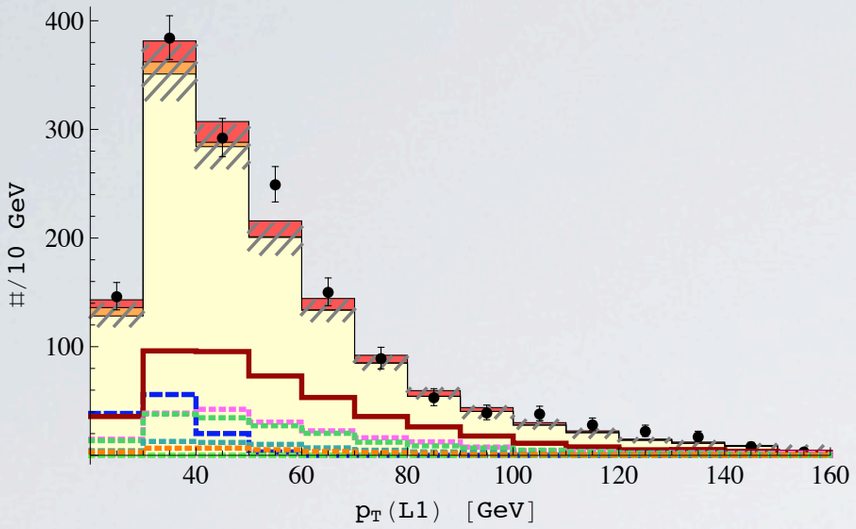
- Chargino NLSP (also have gravity setups with sleptons)
  - low tan beta, large Wino-Higgsino mixing

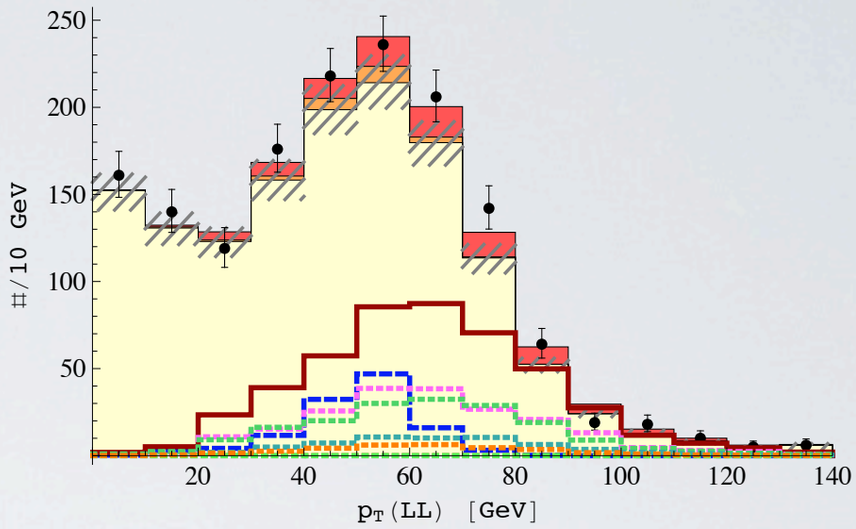


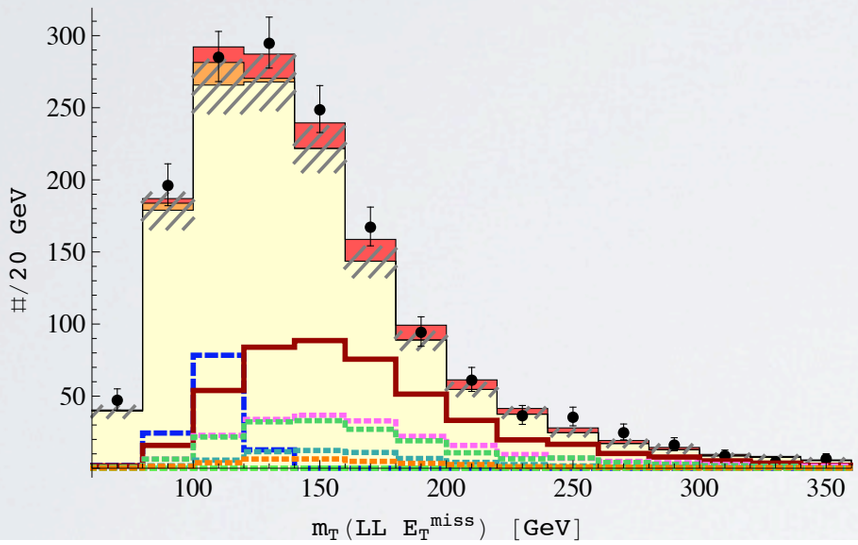


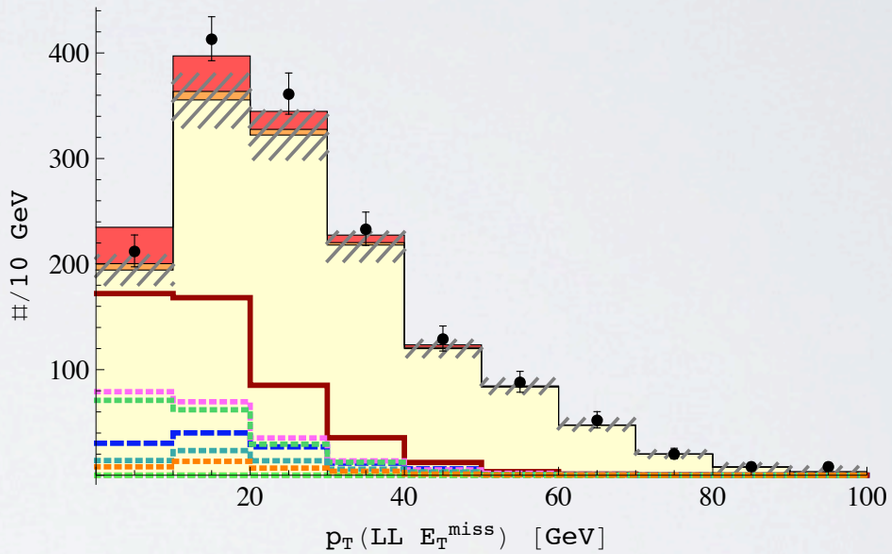
$$m_{\chi_1^\pm} \approx 110\,\mathrm{GeV} \qquad m_{\chi_2^0} \approx 130\,\mathrm{GeV} \qquad \sigma_{NLO} \sim 4.3\,\mathrm{pb}$$
$$m_{\chi_1^0} \approx 113\,\mathrm{GeV}$$

ATLAS 7







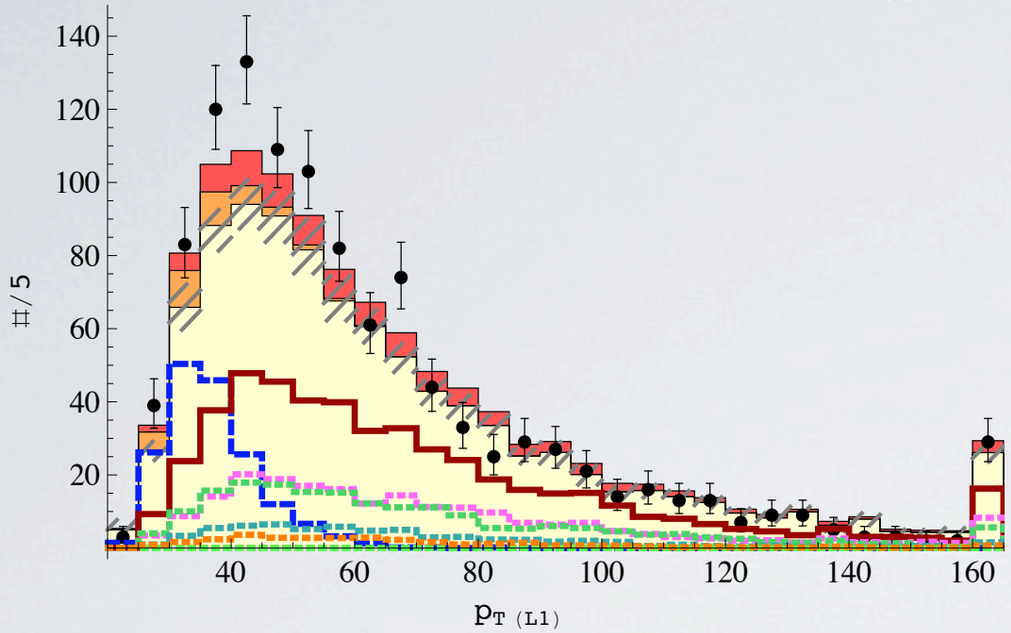


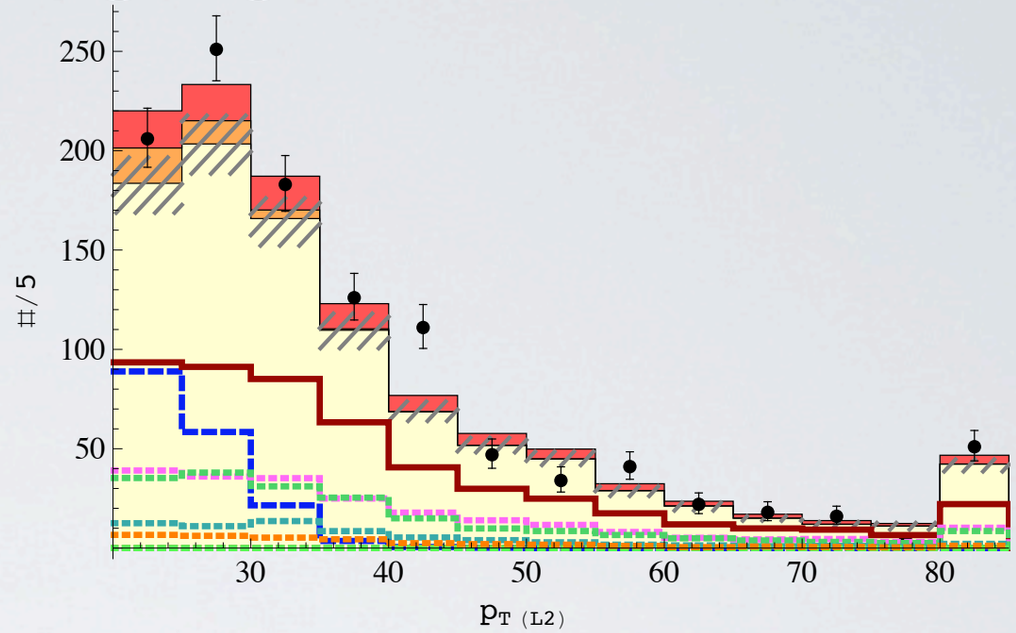
SM prediction | Uncertainty | h → WW | All EWinos | All EWinos x 5 | (h → WW) × 5

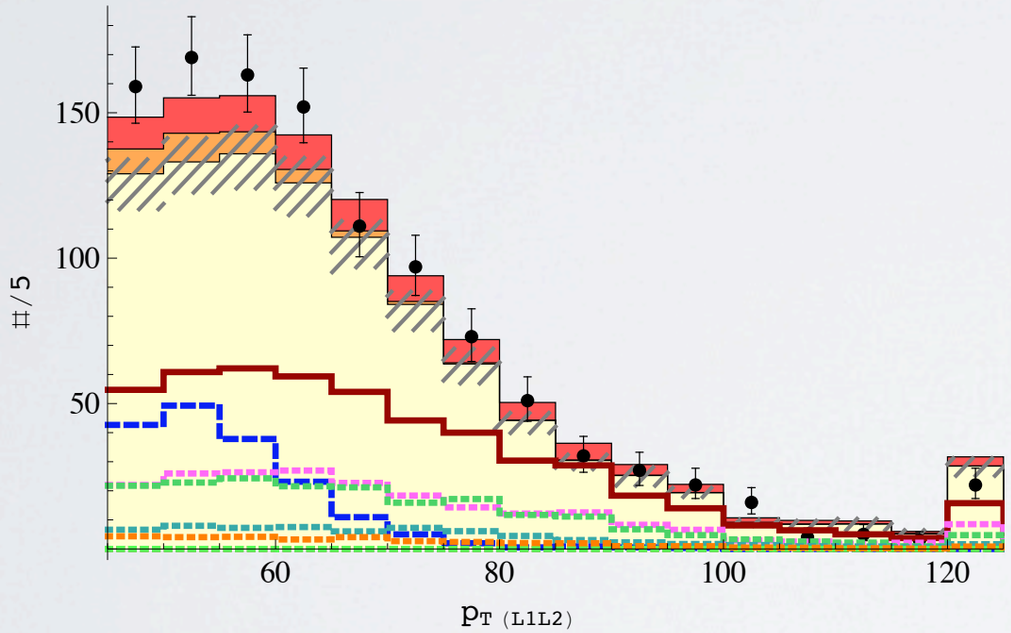
pp → $\chi_1^+\chi_1^-$ | pp → $\chi_1^\pm\chi^0_1$ | pp → $\chi_1^\pm\chi^0_2$ | pp → $\chi^0_1\chi^0_1$ | pp → $\chi^0_2\chi^0_2$ | pp → $\chi^0_1\chi^0_2$

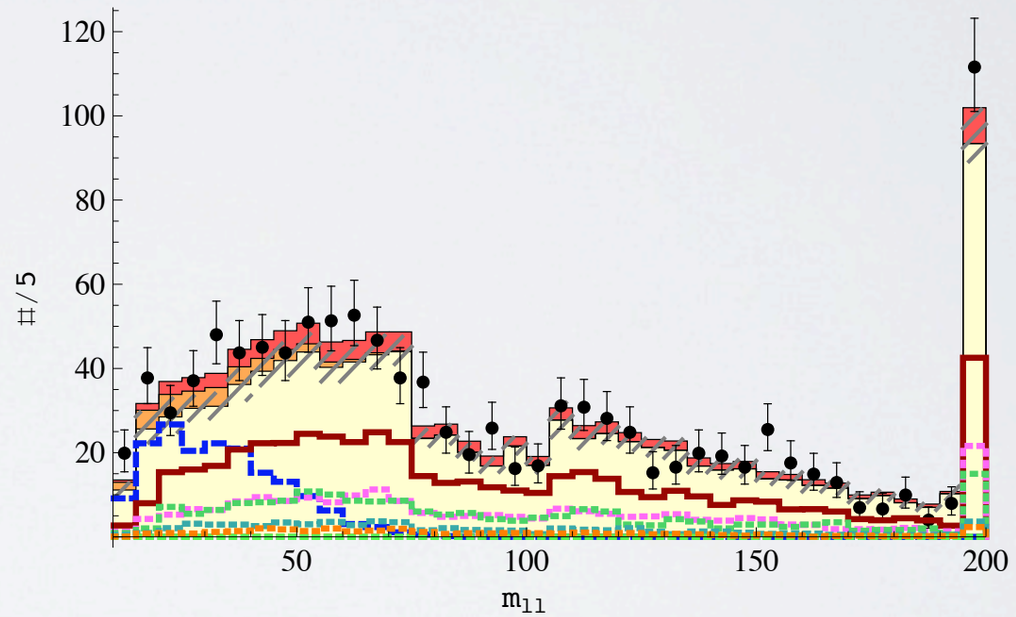
χ^2 cut in **half** compared to SM

CMS 8









SM p-value .001

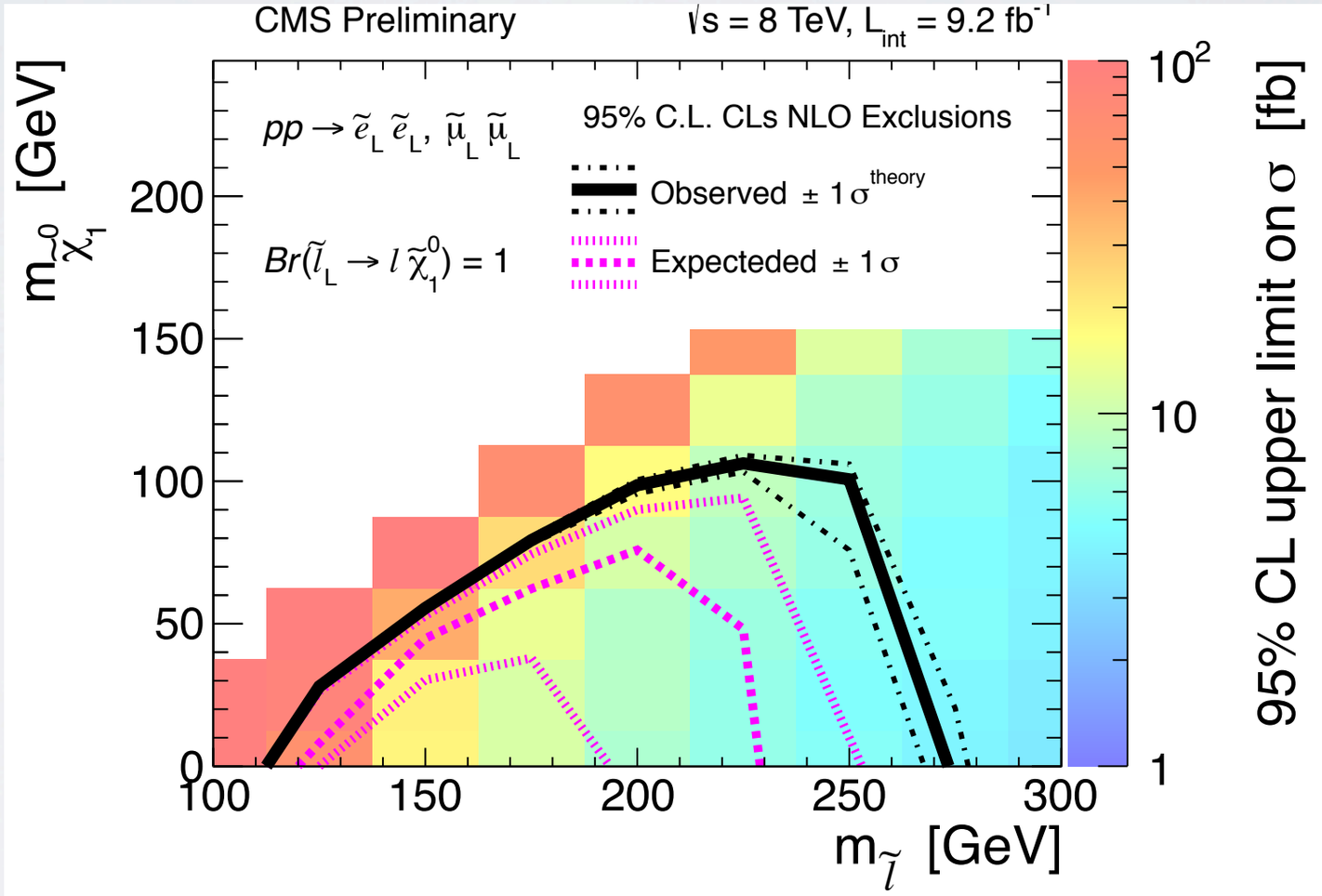
SM+charginos .3

SM+h .1

SM+h+charginos .75

CONSTRAINTS ON THIS SCENARIO

- SS dileptons
- OS dileptons



Remarkably everything works as of ICHEP
Still looking at HCP results!

OTHER EFFECTS FROM NP

- Will not affect $h \to W^+W^-$ **sensitivity** (most models that do this are dead at 9-10 sigma)
    - Shows up in **control** regions
- Amusingly increases $h \to \gamma\gamma$ about 15%
- Same sign dileptons by end of 8 TeV should confirm/rule out
- Other transverse variables that can separate NP/SM WW/QCD

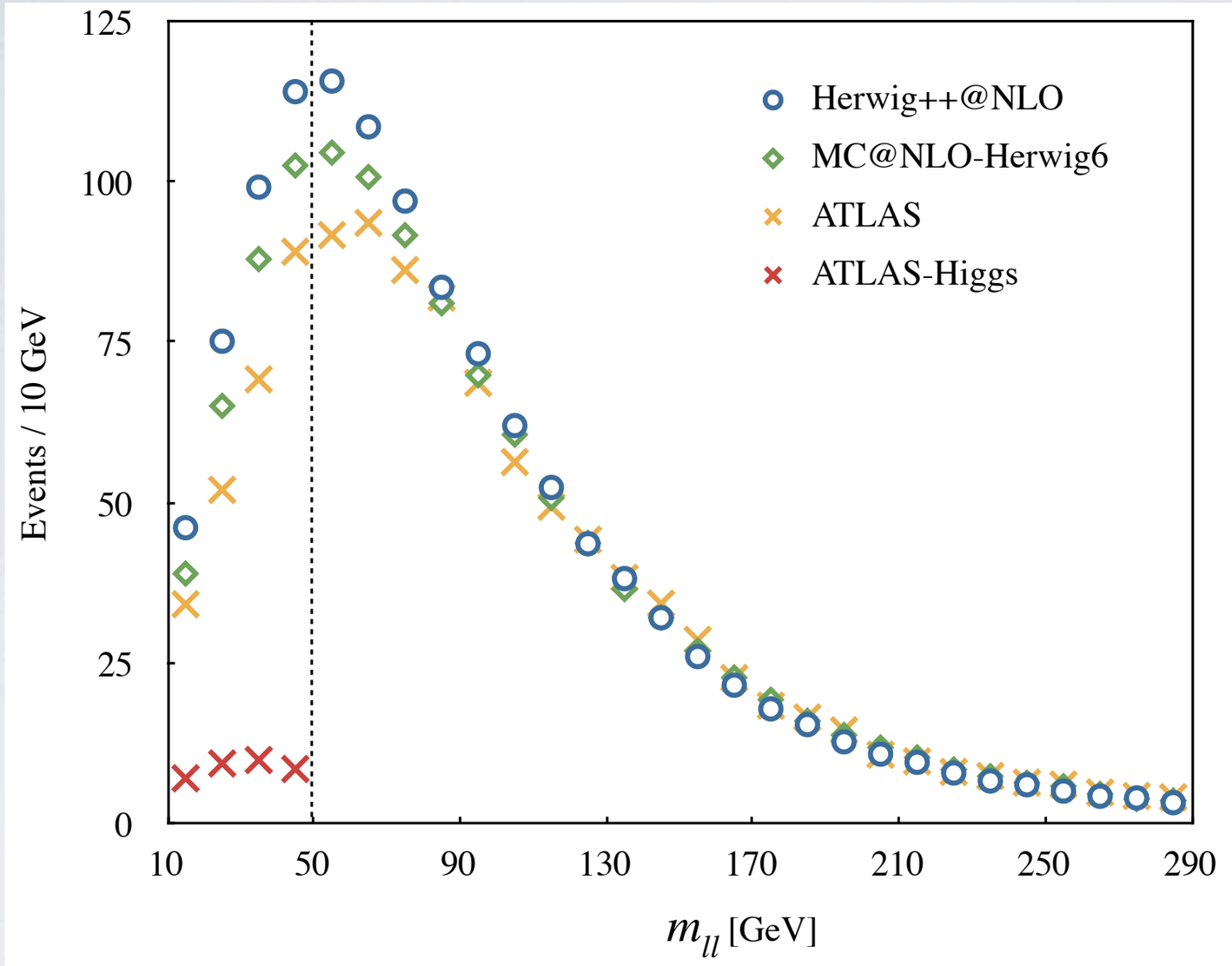
OTHER POSSIBILITIES???

- Backgrounds Wrong - Negligible effect?
- WW cross section wrong (k-factors 1.6ish need a 20% effect)
  - higgs interferes destructively
  - EW NLO reduces as well
- Jet Veto Efficiency - Not what QCD naively wants to do

CROSS SECTION WHAT DO WE KNOW??

- WW cross section @ NLO + parton shower
- What's the variation on this??
  - Apparently a good amount since ATLAS h->WW switched from POWHEG/Pythia8 vs MC@NLO/Herwig for 7 TeV

THEORIST MC SCAN...



Holdom
1211.2729

Implications for Higgs searches!

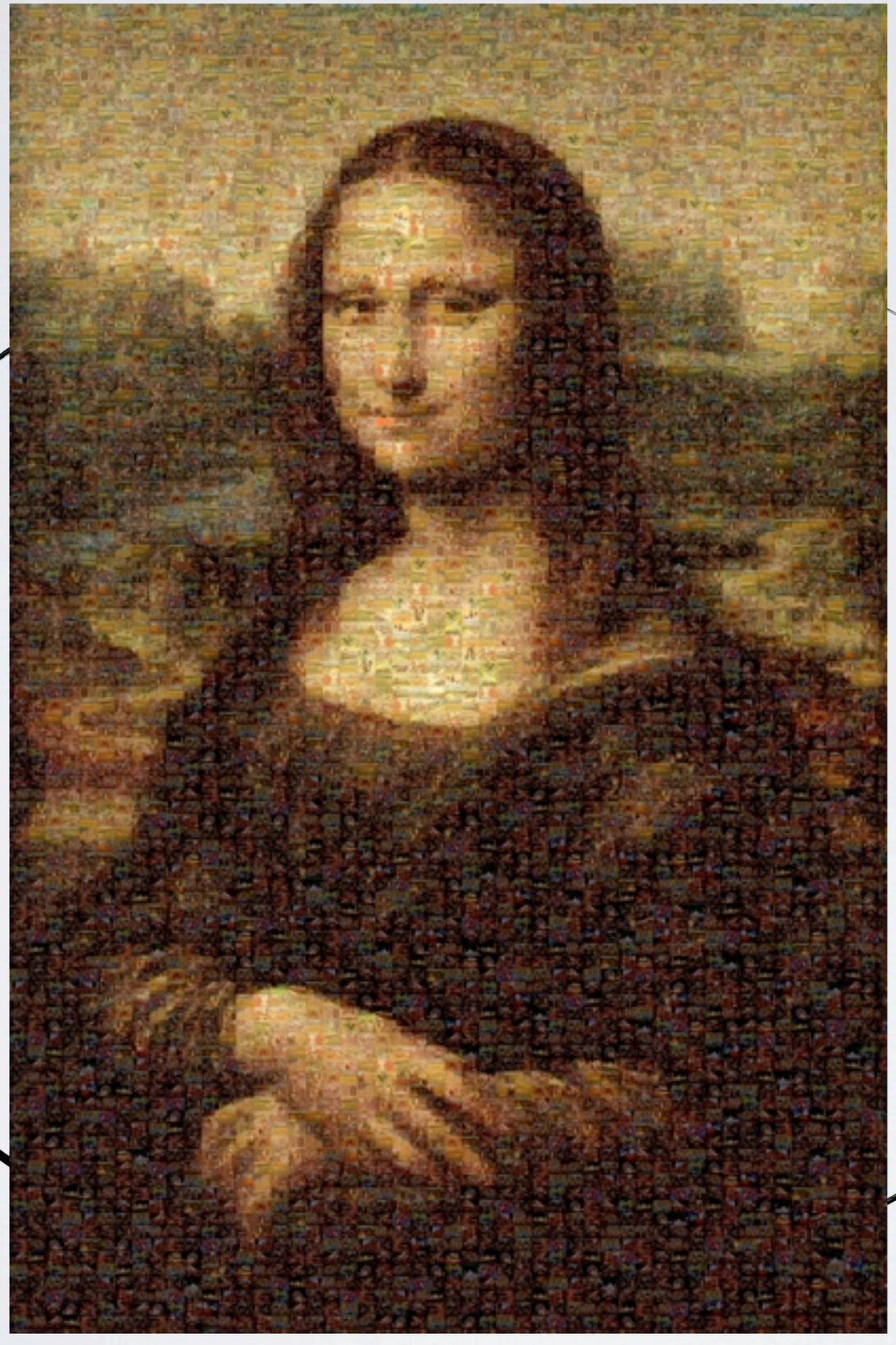
Figure 2: Comparison of $m_{\ell\ell}$ distributions of the WW continuum background normalized in the $80 < m_{\ell\ell} < 290$ GeV region. Only the ATLAS values include the full detector simulation. The two event generators do not include the $gg \to WW$ contribution. Also shown is the simulated 125 GeV Higgs signal in the signal region. ATLAS results are obtained from Fig. (14b) [2].

HOW MUCH DOES THIS MATTER IN THE END THOUGH?

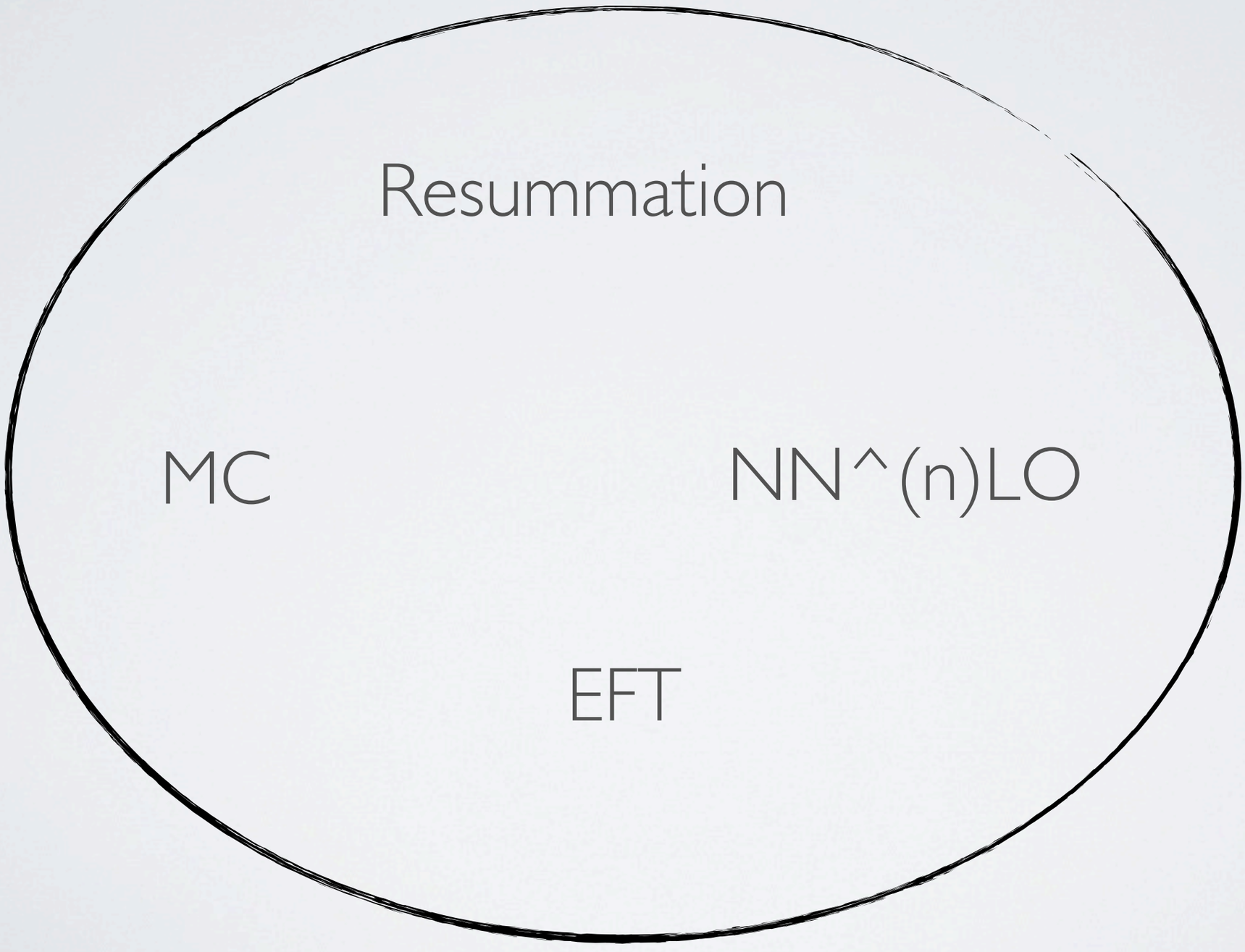
- ATLAS and CMS got the same cross section at 7 TeV
  - CMS uses MADGRAPH for WW!!!??
- We'd like to have some more reliable theory systematic estimate
  - NNLO
  - Resummation

HOW DO WE GO FURTHER?

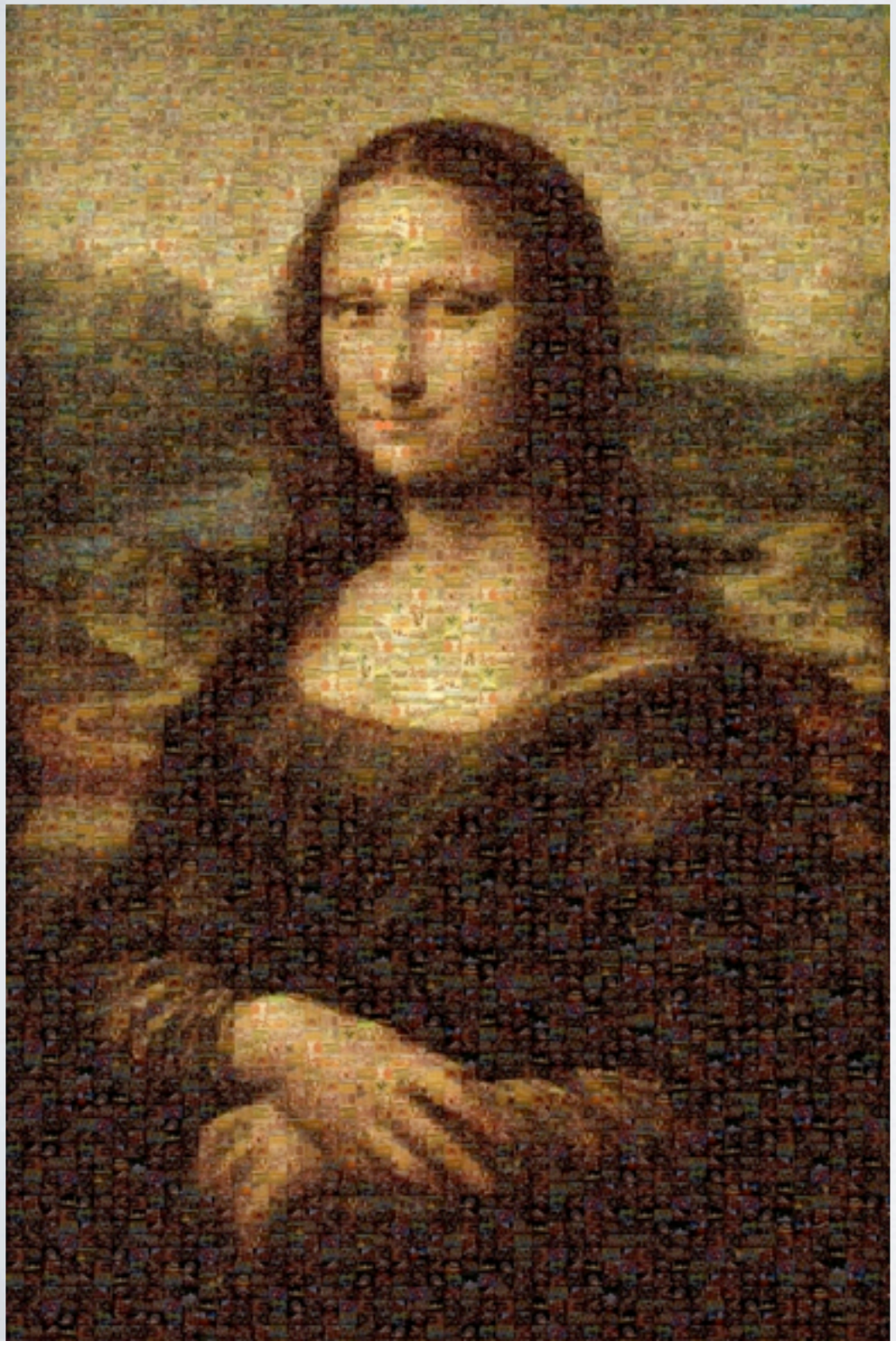
HOW DO WE GO FURTHER?



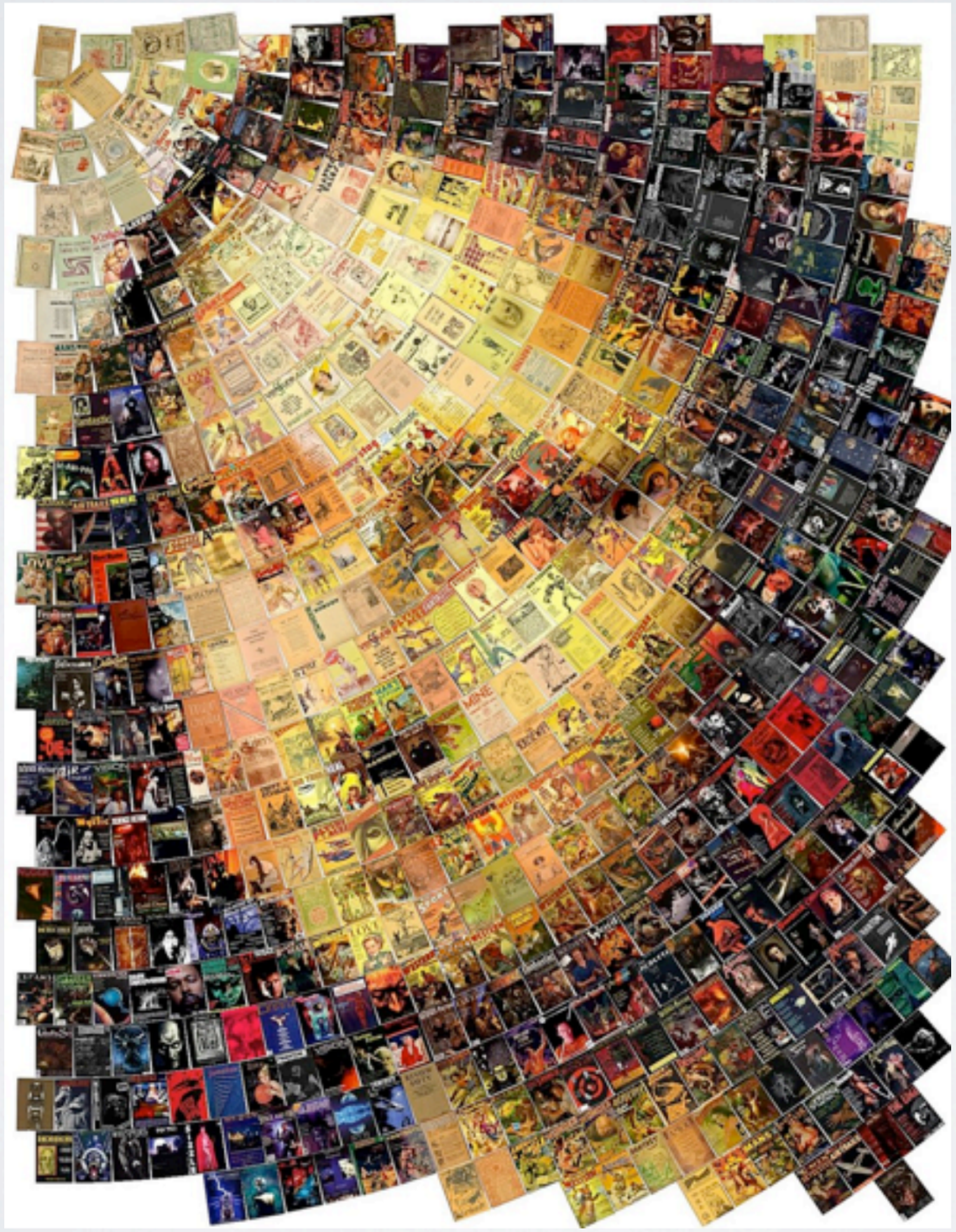
HOW DO WE GO FURTHER?



MASTERPIECE FROM MASTERPIECES?

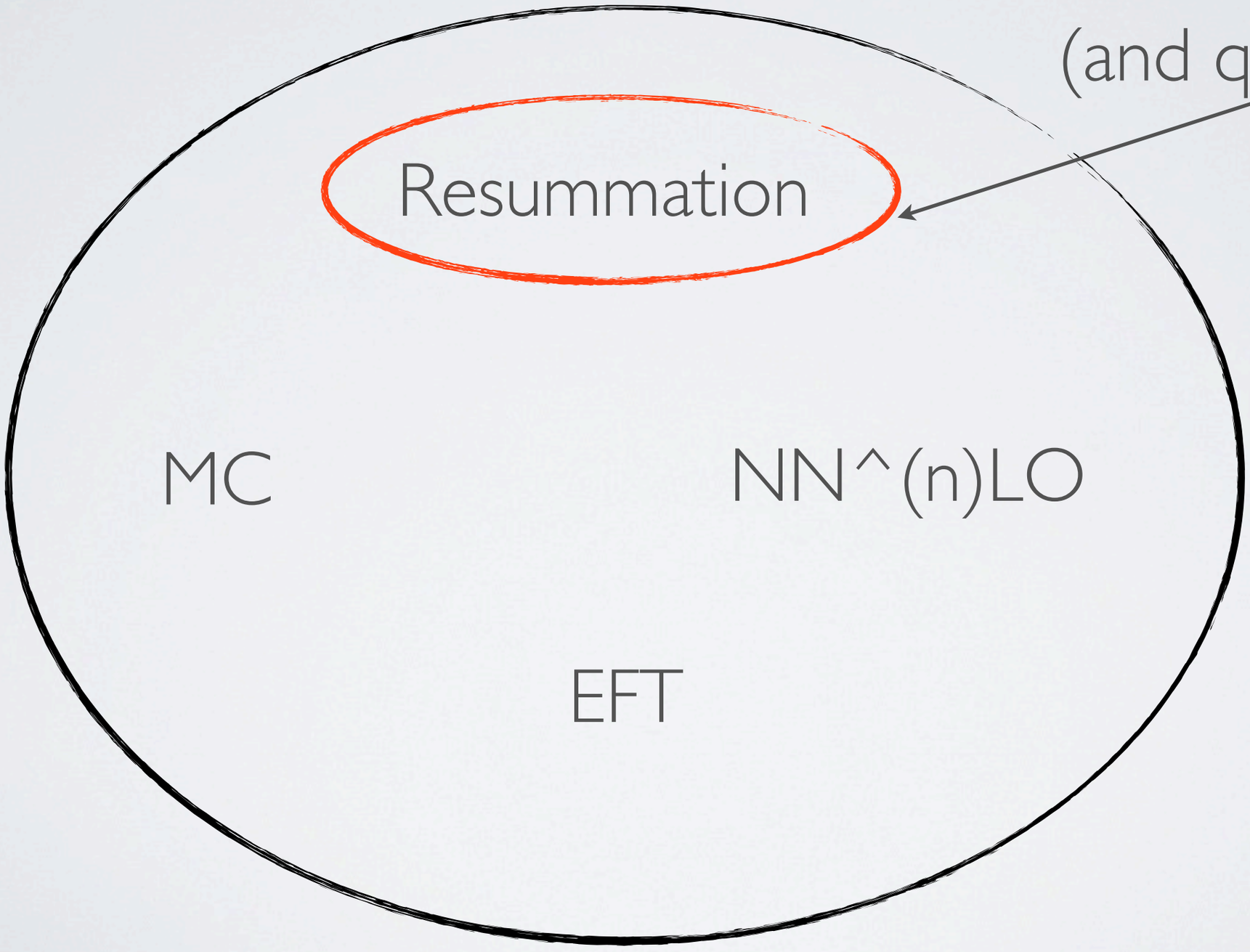


MASTERPIECE FROM OLD MAGAZINE COVERS NO ONE READS AND KNOWS WHAT IS IN THEM?



HOW DO WE GO FURTHER?

How to do this in
the most useful way?
(and quickly)



CONCLUSIONS

- WW cross section is showing a trend from a theorists point of view, to the point that I'm thinking it's not a fluctuation... you can think whatever you want

- New physics CAN explain this and fit better than the SM

- SM calculations should be improved to NNLO+N^(n)LL

- As long as you exclude fluctuation this is a very interesting channel to follow since it has ramifications all over the place...